EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s21**
Version: 1.0

Title: Traceability of high optical laser power measurements via photon force

Abstract

High-power lasers with optical powers > 2 kW are common and a further upscaling of the laser power up to 100 kW is expected. However, the measurement capabilities for such lasers are nowadays limited by the measurement of the optical power by absorbers, i.e. via heat transfer. To overcome this, a new approach should be developed. Photon force is a rather novel idea in optical metrology and opens new opportunities to develop new reference standards for measuring high optical laser power. Although significant progress in measuring optical power using photon force has been recently achieved, many technological challenges must be solved to achieve a measurement uncertainty of less than 1.5 % in the optical power range from 100 W to 10 kW.

Keywords

Photon force, photon momentum, high power laser, laser radiometry

Background to the Metrological Challenges

High-power lasers are used in many applications such as in material processing (for welding, cutting, drilling, marking, etc.), medicine (surgery), and military (as an anti-missile weapon). In all these applications, the optical power of the laser is one of the most important parameters that must be accurately measured to reach the best targeted results.

The optical measurement of high-power lasers is typically carried out using thermal detectors, which from the metrological point of view must be calibrated against traceable reference standard detectors to achieve reliable measurements. Traditionally, cavity-based or flat thermal detectors are used as reference standards by most of the National Metrology Institutes (NMIs) for the dissemination of the radiometric unit Watt at high optical powers. These devices are directly traceable to electrical SI units (volt, ohm) or indirectly through a primary standard for low optical power (cryogenic radiometer). Currently, the uncertainty of optical power measurements achieved with these reference detectors is, in the best case, less than 2 % within the power range from 100 W to 2.5 kW at wavelengths around 1 µm and 10.6 µm. For higher laser power measurements, the use of thermal detectors as reference standard is difficult, since their measurement capability and accuracy strongly depend on the absorbance and heat capacity of the cavity used as sensor. Moreover, the cavity size (total heat capacity) must increase proportionally with the maximum laser power to be measured, and more thermal mass translates to a slower measurement response time.

Exploiting photon force is a rather novel idea in optical metrology and opens new opportunities to develop new reference standards for measuring high optical laser power. The traceability in this case would be to the kilogram. The measurement principle is based on measuring the force imparted by the photon momentum of the radiant power to be measured, on a high-reflectivity mirror.

Photon force is well suited to measure the optical radiant power of continuous high-power lasers and its accuracy can be comparable to or even lower than optical power measurements performed with traditional techniques. Moreover, power sensors e.g. mass scales are simple and offer a cost-effective dissemination of the scale for optical power and its verification over the whole dynamic range. Moreover, since the optical power is measured without absorbing the laser beam, it can be measured with high accuracy while using the laser beam for the intended application. I.e. a real-time monitoring of the laser power is possible.

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

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 protocol.

The JRP shall focus on the traceable measurement and characterisation of new experimental setups, devices and procedures that explore the photon force technique for improving the optical measurement of high power lasers.

The specific objectives are

1. To develop experimental setups and procedures for measuring high optical laser power using the force imparted by the photon momentum. The experimental setups should be based on modified weight balances, microelectromechanical systems (MEMS) and torsion-balances to cover the optical power range from 100 W to 10 kW at wavelengths around 1.0 μm and 10.6 μm. The target uncertainty is < 1.5 %.
2. To assess the technological limits of accuracy of measuring high optical laser power via the photon force due to reflectivity of the mirror, thermal drift, vibrational noise, window transmittance, polarization and other parameters.
3. To compare the linearity characteristics of the photon force technique (via mass scale) with the classical traceability route (via thermal detectors) in the optical power range from 100 W to 10 kW at wavelengths around 1.0 μm and 10.6 μm.
4. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain such as through standards developing organisations and by end users in industry.

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.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the automotive, aerospace and medical equipment manufacturing sectors.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased

- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.