

## **Title: Compact microwave clocks for industrial applications**

### **Abstract**

Accurate and stable time and frequency references are demanded in many of today's activities and infrastructures. The best clocks are developed and maintained in national laboratories and have made significant advances in accuracy in recent years. But those technical advances have been slow to be adopted in the commercial clocks used in industry. This JRP should investigate how high-performing laboratory frequency standards can be developed into compact, reliable and low cost devices, well-suited for operation in an industrial environment, and transfer scientific know-how from the national laboratories to industrial partners to stimulate European production of high performance time and frequency products.

### **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 11.

### **Keywords**

Time and frequency metrology, compact and transportable clock, frequency stability, accuracy, synchronisation.

### **Background to the Metrological Challenges**

A wide variety of industries and technological sectors could benefit from the availability of compact, low-cost and high performing atomic clocks. One such sector is telecommunications which, with its significant growth and an increasing number of remote and underground sites, requires high accuracy references for maintenance and service particularly in base-station synchronisation. Another sector is positioning and navigation where high accuracy local references will open new areas where Global Navigation Satellite Systems (GNSS), such as GALILEO, can be exploited by commercial services.

GALILEO will open three markets for high performance time and frequency products: 1) the space segment requiring space qualified devices to be placed onboard of satellites; 2) the ground segment, where accurate clocks synchronize the onboard clocks; 3) the GALILEO-induced market consisting in signal receivers for positioning and timing. Improved frequency standards may be an excellent candidate for GALILEO clocks, both for space and ground segments.

Compact, high performing clocks are also fundamental to many research fields, such as astrophysics (interferometers for radioastronomy), geophysics (study of Earth rotation, earthquakes, etc.), meteorology and environment (monitoring of the atmosphere, pollution), etc. Local oscillators with high frequency stability in the short and medium term are also required in high resolution spectroscopy.

Secondary frequency standards based on vapour cell technology are well-established, reliable and widely exploited in GNSS applications. But recent developments such as better laser sources and innovative techniques to prepare and detect the atoms, have led to new cell-based prototypes exhibiting unprecedented frequency stability. In some cases, frequency stabilities of the order of  $10^{-13}$  at 1 s with a medium long-term in the range of  $10^{-14}$  or better were measured. These performances are two orders of magnitude better than current commercial rubidium vapour cell clocks.

## 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 development of a clock with performance comparable to that of a H-Maser but with a physics system similar to a Rb clock giving advantages to an industrial user of high accuracy and reliability combined with low cost, power consumption and size.

The specific objectives are

1. To review the possible operational principles based on laser-atom interactions that could be used in such a clock and identify those with the greatest likelihood of meeting the requirements.
2. To build and test possible component systems for such a clock determining the accuracy each could achieve and their sensitivity to environmental parameters.
3. To realise a compact clock with a frequency stability of the order of  $10^{-13}$  at 1 s and in the  $10^{-15}$  range for measurement times up to one day, capable of operating in a typical industrial environment.

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 JRP IND14 “New generation of frequency standards for industry”.

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 timing, frequency and location 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.