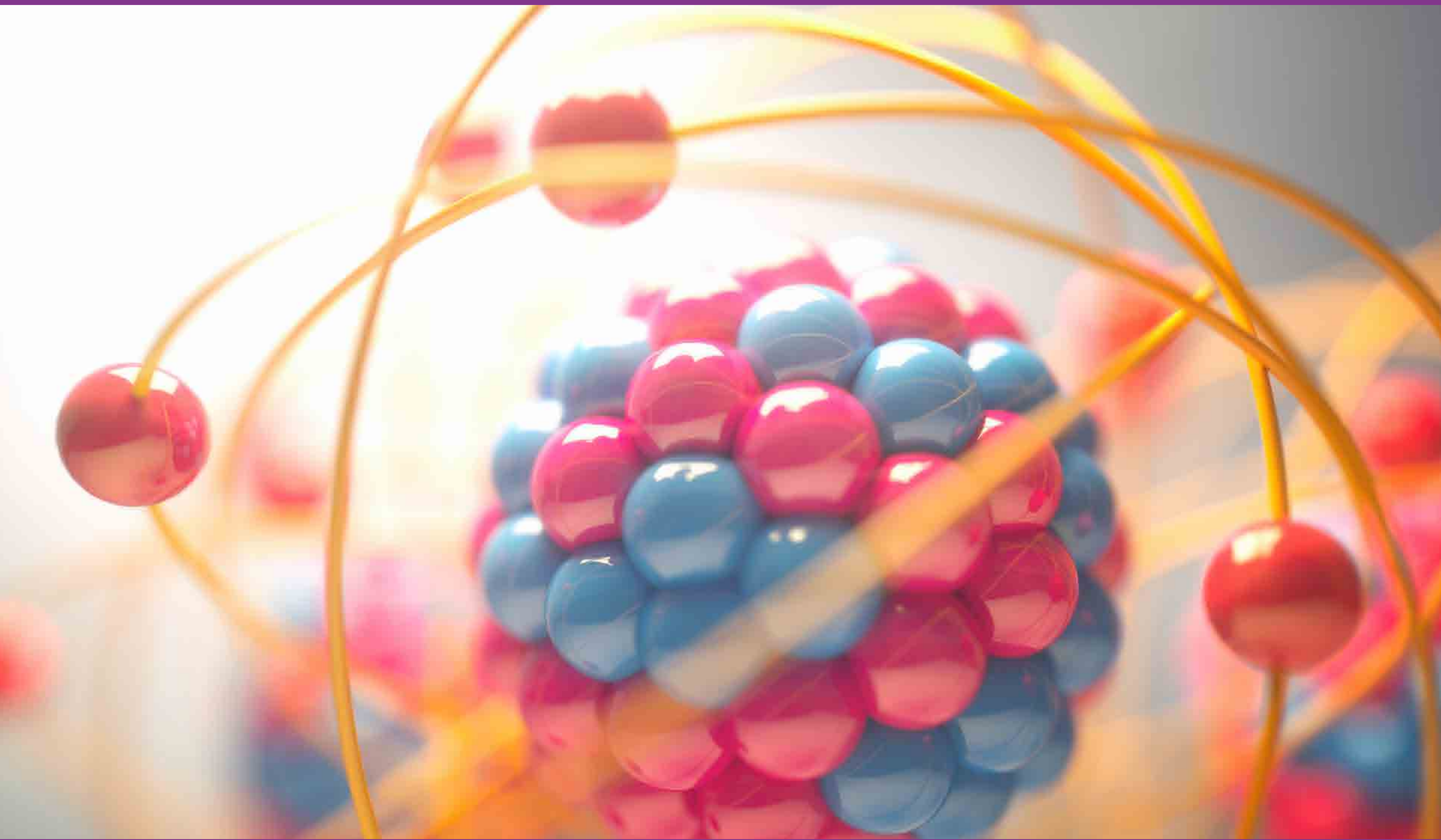
European Metrology Programme for Innovation and Research



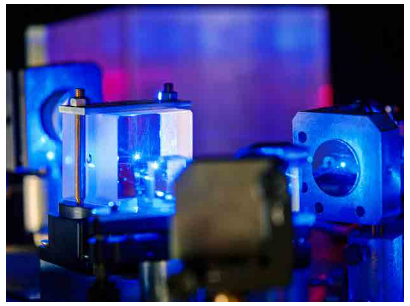
Fundamental Metrology – Projects (Call 2017)

An overview of the funded projects from the Targeted Programme Fundamental Metrology. Research at the frontiers of measurement methods is critical to major advances in science. The aim of these projects is to explore new techniques for use as future metrological methods and primary measurement standards.

EURAMET e.V. - the European Association of National Metrology Institutes

High-resolution optical imaging at the nanoscale

Nanoscale optical measurements with quantum optics and other techniques



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Micro-nanoelectronics, nanotechnology, photonics and advanced materials have been identified by the EU as four strategically important technology sectors; their combined global market is worth €800 billion, with photonics and micro-nanoelectronics employing more than 400,000 people in Europe. As a measurement tool, optical systems have the advantages of speed, non-invasiveness and reliability. However, high technology sectors are increasingly working at the nanoscale, and traditional optics-based measurement systems cannot achieve the spatial resolution required; new techniques therefore need to be developed to overcome current limitations.

This project will develop new optical measurement techniques for the investigation of structures at the nanoscale, with traceable spatial resolution beyond classical limits and sub-nanometre accuracy. Approaches to higher resolution systems include: the development of new 'metamaterial' structures; near-field methods; quantum optics techniques that exploit photon entanglement; the decoding of other information contained in optical waves. End-user events and scientific publications will help promote the uptake of quantum-based and other innovative optics tools in high-technology sectors.

Project 17FUN01

Light-matter interplay for optical metrology beyond the classical spatial resolution limits

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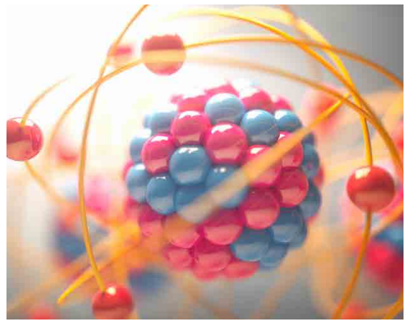
Nuclear decay: improving theory and measurements

Measurement of fundamental nuclear decay data using metallic magnetic calorimeters



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Radioactive elements have been of significant scientific and technological interest ever since their discovery. They undergo change in a variety of ways, Electron Capture (EC) decay being one such pathway. New theoretical calculation techniques and measurement improvements for this process would deliver wide-ranging benefits, including: greater knowledge of the effects of EC decay at the DNA level in cancer therapy; a better understanding of the early history of the solar system; updated and improved radionuclide standards data.

This project will improve novel detection techniques and theoretical models to understand better the behaviour of radioactive elements undergoing EC decay. X-ray emissions from selected radionuclides will be measured more precisely, using recently developed Metallic Magnetic Calorimeters (MMCs) and Microwave Coupled Resonators (MCRs); the high-precision experimental data to be obtained will help validate modelling and calculations. The potential for MMC and MCR detector systems will be demonstrated, with project results delivering improved theoretical methods and standards data for users in nuclear physics.

Project 17FUN02

Measurement of fundamental nuclear decay data using metallic magnetic calorimeters

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Optical clocks: a next-generation quantum technology

Exploiting optical clocks for time measurement and sensor development

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From advanced navigation and telecommunications to radio astronomy and the testing of fundamental physical laws, the most precise and accurate time measurements are required. To meet these technical challenges, optical clock development is at the forefront of research in this field. The state-of-the-art technology, however, has its limits: frequency stability of the lasers used in such systems is affected both by thermal noise from mirror coatings and more fundamentally by so-called quantum projection noise (QPN). Advanced quantum-based sensors could also be realised if current technical constraints could be surpassed.

This project will implement, study and characterise both established and new methods for the development of optical clocks. To go beyond noise limits and increase frequency stability, multi-particle entanglement of atoms/ions will be investigated; this phenomenon could also be exploited for electromagnetic field measurements with enhanced sensitivity. The project results will support future realisations of the SI second through new frequency standards and significantly impact many fields requiring ultra-precise time measurement.

Project 17FUN03

Ultra-stable optical oscillators from quantum coherent and entangled systems

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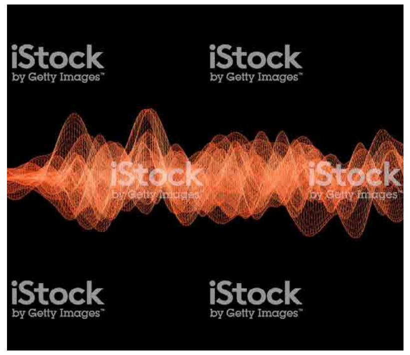
Advances in quantum technology: single-electron devices

Semiconductor single-electron quantum optics for electromagnetic field sensing



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In the quantum world, electrons can exhibit wave-like properties, and this behaviour is being exploited in new technologies based on developments in the field of single-electron quantum optics. Fabricated from semiconductor materials, these novel devices will include applications such as electromagnetic field sensing. The challenge is to develop components that harness the wave-like nature of single electrons, understand their quantum behaviour, and create the tools needed for device characterisation.

This project will fabricate semiconductor-based devices exploiting quantum properties of individual electrons for innovative sensors and other components, such as on-demand single electron sources. The methods needed to characterise the electrons' so-called quantum states will also be developed. For electric and magnetic field detection, a new sensing technique will be used to demonstrate high spatial and temporal resolution (~ 1 µm and ~ 1 ns or below, respectively). Both practical and theoretical results from the project will be used to promote the uptake of single-electron wave packet devices, and the associated measurement techniques, to characterise their performance.

Project 17FUN04

Single-electron quantum optics for quantum-enhanced measurements

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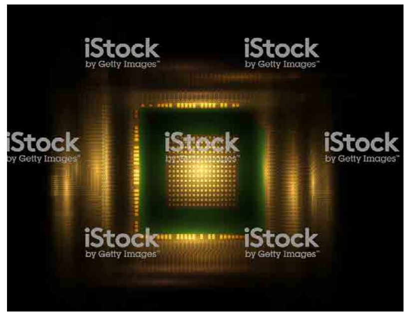
Nanotechnology for advanced temperature measurement

Photonic and optomechanical sensors for nanoscale and quantum thermometry



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For a wide range of processes, from consumer electronics to space instrumentation, there is a growing need to make temperature measurements at smaller scales. The range of currently available thermometers, however, cannot meet the challenge. Nanotechnology now offers the possibility of innovative 'optomechanical' sensors capable of measuring temperature on micrometre length scales. Not only could these new temperature sensors replace the standard high-accuracy platinum resistance thermometers but, embedded into production processes, many industrial users could benefit from the technology.

This project will design, fabricate, and characterise different optomechanical systems for temperature measurement. Calibration methods will also be developed to make the sensors traceable to the International Temperature Scale of 1990 (ITS-90). Beyond sensing capability on the micro- and nano-scale, other advantages include reduced cost, better portability and robustness, and increased resistance to mechanical shock and electrical interference. Additionally, optomechanical sensors could be developed as a future quantum-based primary standard for temperature measurement.

Project 17FUN05

Photonic and Optomechanical Sensors for Nanoscaled and Quantum Thermometry

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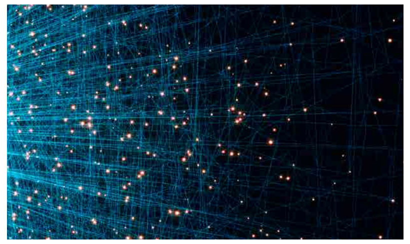
Generating single-photon sources

Improving sources of single photons to accelerate quantum technology innovation



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Technologies based on the laws of quantum mechanics are the next stage of industrial and scientific innovation. With far-reaching applications, from super-fast computers and ultra-secure communication to sensitive sensors for biomedical imaging, they will help to provide solutions to many of today's global challenges. A fundamental building block of optical quantum technologies are light sources that can emit single photons. However, despite large steps forward, current single-photon sources are still insufficient for real, practical uses.

This project will carry out the fundamental work needed to develop a new quantum standard, assessing and establishing new materials and designs for single-photon sources. It will also develop essential elements of supporting measurement infrastructure, such as amplifiers and detectors. By providing access to better single-photon sources, this project will catalyse future innovation in the field of optical quantum technology, and could contribute towards the realisation of a quantum definition of the luminous intensity SI base unit, the candela.

Project 17FUN06

Single-photon sources as new quantum standards

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Ultra-precise optical clocks

Investigating the next generation of atomic clocks

Atomic clocks form the basis of international time keeping, providing highly accurate time to a wide range of sectors around the world. The next generation of atomic clocks are based on optical frequencies using laser-cooled trapped ions. These ultra-precise optical clocks hold significant promise for increasing measurement accuracy and stability, and rapid progress has been made in reducing their uncertainties. To continue to optimise optical clocks for commercial applications such as communication and navigation, further understanding and control of ion sources is needed. This in turn requires that the necessary experimental equipment is made accessible.

This project will investigate laser-cooled trapped ions for optical clocks, examining the characteristics of multi-ion sources. It will also implement an advanced form of laser cooling, and develop transportable equipment to enable experiments to be carried out at nuclear physics and optical measurement laboratories. By supporting the reliability and precision of trapped ion optical clocks, this project will help to meet growing industry need for accurate time, and provide an essential contribution to any future revision to the second, the SI unit for time.

Project 17FUN07
Coulomb Crystals for Clocks
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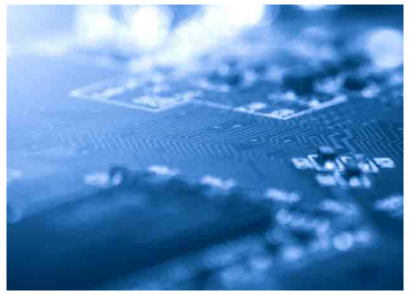
Investigating spintronic structures

Characterising materials to increase the understanding of spintronics – the next generation of electronics

Smaller, faster, and more efficient electronic devices are a vital part of Europe's economic growth and industrial innovation, and could significantly contribute to its goal of a 20 % reduction in CO_2 emissions by 2020. Spintronics, which uses a fundamental property – intrinsic spin – of electrons to process information in a way that is analogous to charge in traditional electronics, holds potential to meet such aims. Researchers have begun exploring materials that have geometric structure which protect the configuration of electrons' spin. These are known as topologically-protected spin structures (TSS), and could enable greater data storage and device efficiency. However, fundamental understanding and reliable characterisation tools for TSS are still lacking.

This project will develop and validate measurement tools and techniques for describing TSS, helping to identify key parameters that determine the formation, size, and stability of TSS. By performing fundamental investigations on spintronics, the project aims to progress TSS towards standardisation and support Europe's continuing expertise and competitiveness in electronic device manufacturing.



Project 17FUN08
Metrology for topological spin structures
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A universal pH scale

Practically implementing a unified method for assessing acidity

pH is one of the most important chemical properties measured in both science and industry, playing a vital role in health, environmental studies, and material reprocessing. With potential to impact an extensive range of sectors, accurate analysis and monitoring of pH is essential. Due to theoretical and practical constraints, the comparison of pH between different media has not been possible and over the last century this has led to the formation of several incompatible pH scales. In 2010 the concept of a unified acidity scale, pHabs, was devised to overcome this issue, but it has proved challenging to implement.

This project will put pHabs into practice by establishing a reliable and universally applicable procedure for measuring the acidity of any substance. It will also develop a validated set of calibration standards for a wide variety of media. In striving towards a practical and accurate unified pH scale, this project will support and strengthen EU manufacturing and innovation in industries from pharmaceuticals to petrochemicals and semiconductors.

Project 17FUN09
Realisation of a Unified pH Scale
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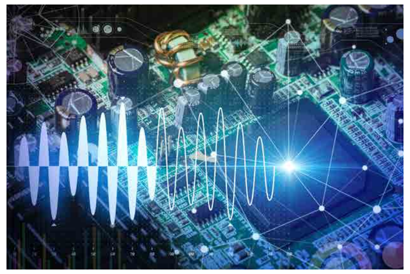
A new cryogenic microwave amplifier

Developing technology for microwave quantum optics

Technologies that harness quantum mechanical phenomena are expected to advance a wide range of industries, from communications to medical imaging, by offering functionality unattainable to classical machines. The emerging field of microwave quantum optics has garnered significant interest for the development of such technologies, but its progress critically depends on the availability of devices, cooled to extremely low temperatures, that amplify microwave signals. Currently, even state-of-the-art cryogenic amplifiers suffer electrical noise that is too high for quantum experiments and circuits. The Josephson Travelling Wave Parametric Amplifier (JTWPA), has been proposed conceptually as a potential solution.

This project will develop a JTWPA, and prepare components and processes to characterise its properties. The project also aims to integrate the JTWPA with quantum sensors and macroscopic quantum systems. Investigating the capabilities of the JTWPA is a first step towards the advancement of microwave quantum optics, which could impact many fields of science and technology, such as artificial intelligence, cryptography, and brain scans.



Project 17FUN10
Josephson travelling wave parametric amplifier and its application for metrology
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Europe's National Measurement Institutes working together

The majority of European countries have a National Measurement Institute (NMI) that ensures national measurement standards are consistent and comparable to international standards. They also investigate new and improved ways to measure, in response to the changing demands of the world. It makes sense for these NMIs to collaborate with one another, and the European Association of National Metrology Institutes (EURAMET) is the body that coordinates collaborative activities in Europe.

The European Metrology Programme for Innovation and Research (EMPIR) follows on from the successful European Metrology Research Programme (EMRP), both implemented by EURAMET. The programmes are jointly funded by the participating countries and the European Union and have a joint budget of over 1000 M€ for calls between 2009 and 2020. The programmes facilitate the formation of joint research projects between different NMIs and other organisations, including businesses, industry and universities. This accelerates innovation in areas where shared resources and decision-making processes are desirable because of economic factors and the distribution of expertise across countries or industrial sectors.

EURAMET wants to involve European industry and universities at all stages of the programme, from proposing Potential Research Topics to hosting researchers funded by grants to accelerate the adoption of the outputs of the projects.

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