EDF-2021-DIS-RDIS: Research for disruptive technologies for defence applications

Proposals are invited against the following topic:

EDF-2021-DIS-RDIS-QSENS: Quantum technologies for defence

Budget

The Union is considering a contribution of up to EUR 60 000 000 to support proposals addressing the abovementioned topics and their associated specific challenge, scope, targeted activities and main functional requirements.

A lump sum approach will be used. For selected projects, the maximum EU contribution will be based on the eligible costs in the requested funding, but actual payments will be conditioned to the completion of work packages. Proposals should include clear descriptions of the proposed criteria to assess work package completion.

Several actions, addressing different topics, may be funded under this call.

Quantum sciences have the potential to be a disruptive technology for a wide range of application domains including defence. At the core of this "second quantum revolution" is information: its acquisition (quantum sensors, quantum imaging), its transmission (quantum communications) or its processing (quantum computation).

In the long term, quantum communications or digital superiority by quantum computing are two examples of how quantum technologies can benefit defence applications.

In a shorter-term, quantum sensors are expected to play a major role in offering unprecedented advantages in a defence context. Thanks to quantum physics, new sensors are tested in laboratories with precision not achievable before.

Specific challenge

This topic aims to push the undergoing technological effort, taking into account the special requirement of the defence sector.

The possession and deployment of quantum technologies will be a game changer in many application domains, which means that maturing and mastering these technologies is a must for mission superiority, but also competitiveness. Europe and European countries fully engage to support this technological development, but are currently outpaced by other countries especially China and the United States. This topic proposal aims at filling this gap.

Scope

The ambition is to explore and demonstrate quantum technology solutions in mainly three applicative directions, namely:

(1) Positioning, navigation and timing,

(2) Quantum radio frequency sensing and

(3) Quantum optronics sensing.

Developments concerning specific enabling technologies are intended to be included. Indeed, most of enabling technologies exist already in laboratories. They need now to reach the necessary maturity to meet military operation conditions. This may include: compact cryogenic systems for quantum technologies, fast electronic devices for quantum technologies, specific sources of light for quantum technologies, integration of photonic systems.

Quantum radar (based on entangled RF photons, i.e. quantum RF illumination) must not be considered in the proposals since preliminary system analysis have shown operational gains only in very specific and reduced domains of applications.

Some activities covered by the proposals could share multiple communalities, for example in terms of enabling technologies, with other quantum domains of applications (e.g. communication, encryption). Whilst not being the objective of this call topic, the proposals should elucidate potential benefits of current works for these other quantum domains of applications.

Targeted activities

The proposals must cover the following activities as referred in article 10.3 of the EDF Regulation, depending on the topics addressed according to the functional requirements:

- Activities that aim to create, underpin and improve knowledge, products and technologies, including disruptive technologies for defence, which can achieve significant effects in the area of defence;
- Activities that aim to increase interoperability and resilience, including secured production and exchange of data, to master critical defence technologies, to strengthen the security of supply or to enable the effective exploitation of results for defence products and technologies;
- Studies, such as feasibility studies to explore the feasibility of new or upgraded products, technologies, processes, services and solutions;
- The design of a defence product, tangible or intangible component or technology as well as the definition of the technical specifications on which such a design has been developed, including any partial tests for risk reduction in an industrial or representative environment

In particular, for each technical area as referred in the functional requirements, the proposals must include some or all of the following activities:

- Analysis of the disruptive potential of specific quantum technology capabilities in defence applications;
- Analysis of the technical feasibility, requirement specification, trade-offs and concept definition for an operational use case;
- Development of a demonstrator system for an operational use case and maturation of quantum technology components;
- Performance verification in a relevant environment such as a testbed aircraft or a research vessel;
- Analysis of industrialization and technology maturation needs.

Functional requirements

The proposals must include activities regarding at least one the following topics and comply with the related requirements:

(1) Positioning, Navigation and Timing quantum sensors for Defence

- **High performances atomic clocks**

New concepts of atomic clocks could provide orders of magnitude improvements in terms of frequency stability and compactness compared to standard designs. They tend to become SWaP[1] compatible with on-board platform integration and to allow new collaborative combat and measurement schemes, requiring for example the synchronization of multiple platforms in Global Navigation Satellite System (GNSS) denied, degraded or contested situations. In addition, the impact of clock sources, such as those used to improve the resilience of strategic communication networks or the continuity of essential services, is of high interest, as well as the technical means to distribute such clock signals.

The proposals must address new concepts of atomic clocks significantly improving currently available frequency stability in a compact form factor. Specific developments of enabling technologies such as low-noise laser sources, compact optical benches, photonic integrated circuits and compact atomic vapour cells must also be considered.

- **Cold atom based inertial sensors**

The use of cold atom interferometers is known to bring disruptive possibilities to develop compact multifunctional inertial measurement units, which have the capacity to drastically improve autonomous navigation. The bandwidth of these sensors will benefit from hybridization with classical accelerometers and gyrometers (e.g. MEMS[2] and FOG[3]).

The proposals must demonstrate functionalities such as accelerometry, gyrometry and combination of these functionalities with time measurements to significantly improve autonomous positioning and navigation. Specific developments of enabling technologies such as compact electronics, photonic systems or vacuum systems must also be considered, with the perspective of a SWaP integration of these functions.

- **Cold atom based gravimetry**

Cold atom based gravimetry will allow the creation of accurate gravity maps leading to new applications in terrain aided navigation, calibration of inertial measurement units before mission start and higher accuracy gravimetry correction for strap down navigation. These will lead to enhanced capability for autonomous navigation.

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[1] Size, weight, power
[2] Microelectromechanical systems
[3] Fiber Optic Gyro

The proposals must include activities demonstrating the feasibility of cold atom based gravimetry for navigation. Specific developments of enabling technology such as compact narrow linewidth lasers and compact vacuum system must also be considered.

- **Levitated inertial sensors**

Optical fields and AC electric field can be used to exert forces on material particles and levitate them in a vacuum environment. These systems can be used as inertial sensors, to probe accelerations, rotations and gravitational fields. Such sensing devices can reach quantum regimes of detection, thus reducing the internal noise of the device.

The proposals must address the possibility of packaging these systems in a sub-centimetre scale, remotely controlling them with optical fibres, and examine the versatility of deployment options, making them a disruptive technology that will allow a new range of military applications.

- **Optical fibre inertial sensors**

Optical fibre sensors are mechanically robust, lightweight, cheap, totally passive, and immune to electromagnetic interference and can be read out also by km distance with a completely passive operation. Ultra-high bandwidth vibration, acceleration and rotation sensors with sensitivity performance well beyond the state of the art can be developed harnessing cutting-edge laser optical quantum technologies in combination with telecom-grade optical fibre components. Compact interferometric structures relying on optical fibre elements and resonators can be interrogated with non-classical light sources and single-photon detectors.

The proposals must include activities regarding this topic which can lead to systems likely to be disruptive in real-time monitoring of ground movements, residential structures, air/surface vehicles as well as high-precision underwater navigation.

- **Solid-state quantum vector magnetometers**

Solid-state magnetometers based on colour centres in crystals, such as Nitrogen vacancy (NV) centres in diamond, are quantum devices operating at room temperature that offer highly sensitive, compact, and low power-consumption solutions to reconstruct full vector magnetic field maps. These systems can lead to enhanced capabilities in navigation and geo-referencing based on magnetic anomaly maps.

The proposal must address new sensing schemes and concepts for quantum vector magnetometry significantly improving currently available sensitivity and resolution. The development of enabling technologies such as microwave electronics, optical integration techniques, material engineering, imaging methods, readout architectures or signal processing must be considered.

(2) Quantum radio frequency sensing for defence

- **Quantum Technologies for high sensitivity RF sensing**

The proposals must address the potential gain in performance that can be achieved using quantum technologies to sense classical RF illumination.

Quantum systems such as ensembles of atoms in Rydberg state or superconducting quantum devices exploiting interference effects are promising new EM fields sensing schemes offering unprecedented sensitivity and accuracy. These approaches, amongst others, could allow compact antenna or sensing schemes over large frequency bandwidth, exchanging the usual "antenna gain" of classical/large sensors for the gain in sensitivity provided by compact and potentially covert quantum based devices. The proposal must include activities regarding this topic.

All dielectric, highly compact and intrinsically calibrated ultra-wideband (MHz-THz) RF field sensors can be envisaged for instance with Rydberg atoms at room temperature. To demonstrate their practical implementations and performances compared to standard antennas, the proposal must investigate optimized optical excitation and interrogation schemes, in parallel with enabling technologies such as frequency controlled laser sources at specific wavelengths, compact atomic vapor cells and optical integration techniques.

Superconductive devices based on Josephson Junctions have proved astonishing level of sensitivity even at temperature >30K, which makes them solid candidates for both magnetic anomaly detection and sensor applications where miniaturized antennas with high performance are required. In this domain, it is necessary to optimize technological features in order to reach reliable wafer-scale fabrication process. The proposal must include activities demonstrating the feasibility of such detectors and showing their superiority over current detectors. As an enabling technology, the development of compact cryogenic solutions must also be considered.

- **Quantum Technologies for electronic intelligence (ELINT)**

Quantum sensing offers unique opportunities for electromagnetic landscape monitoring and ELINT. NV centres in diamond and more generally colour centres in crystals could allow the realization of compact solid-state spectrum analysers or RF signal classification schemes covering most of the radar frequencies and working at room temperature. Improving their performances requires enhanced sensing schemes and concepts, high quality material, optimized RF antenna, controlled magnetic field, low noise optical detection.

The proposals must include activities demonstrating the feasibility of such detectors and showing their superiority over current detectors. The development of several enabling technologies such as material engineering, microwave electronics, optical integration techniques, optimized imaging methods, new signal reading architectures or signal processing must also be considered in order to achieve compact sensors with optimized performances for ELINT.

(3) Quantum optronics sensing for Defence

- **Active systems based on non-classical illumination**

The proposals must address both quantum illumination with entangled photons (e.g. quantum LIDAR[4]) and more generally exploitation of quantum technologies for optronics sensing and imaging.

[4] Light detection and ranging

Multiple quantum imaging schemes have been proposed to improve the performances of active optronics remote sensing systems in terms of sensitivity, covertness and hacking/jamming robustness, and also to offer the capability to operate in poor propagation conditions and Degraded Visual Environment (fog, rain...).

The proposals must investigate their impact on operational capabilities and their practical implementation. Examples of schemes to be explored include quantum ghost imaging (QGI) and quantum LIDAR based on entangled photons sources, 2D/3D imaging based on single photon array detectors, broadband multispectral sensor... Specific developments in enabling technologies must also be considered, including for example single photon bucket detector, high resolution and gated single photon array detectors (SPAD), efficient entangled photon sources for QGI and quantum LIDAR, graphene & quantum dot for visible and infrared light sensors, quantum detectors/modulators (QWIP[5], QCD[6],...).

- **Passive systems based on Quantum Technologies**

Passive systems for optronics sensing could also benefit from quantum technologies. In analogy to RF sensing, passive optronics systems can be improved both in terms of sensitivity and of functionalities, harnessing devices and concepts based on conventional photo-switch quantum technology based devices and concepts.

Examples of schemes to be explored by the proposal include: photon statistical analysis (analogous to the Hanbury Brown and Twiss effect) and thermal ghost imaging, ghost Mach-Zehnder interferometry, and more generally coherent detection of thermal photons. Such schemes are expected to provide additional or improved capabilities such as lens less ghost imaging, increased spatial resolution for thermal imaging, optical imaging/detection of phase objects, and imaging/detection of gas (leaks or CBRN[7]). Specific developments in enabling technologies must also be considered, including single photon bucket detector, SPAD, QWIP/QCDs, MEMS-based optical sensors, low noise/large coherence QCLs[8]/ICLs[9].

Expected impact

- Efficient GNSS-free navigation based on quantum inertial sensors, anomaly mapping and reliable micro-atomic clocks;
- Innovative and accurate quantum enhanced RF sensors operating in a defence context;
- Innovative and accurate quantum optronics sensors and imaging systems operating in a defence context;
- Development of EU supply chains for specific enabling technologies that are considered essential to master the overall capability.

[5] Quantum well infrared photodetectors
[6] Quantum cascade detectors
[7] Chemical, biological, radiological and nuclear
[8] Quantum cascade lasers
[9] Interband cascade lasers