QUANTUM TECHNOLOGIES

PUBLIC POLICIES IN EUROPE

QUANTERA

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2020

QUANTERA

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Introduction

Quantum Technologies (QT) is a highly interdisciplinary, paradigm--changing area of research. European researchers have been at the forefront of these developments, delivering many ground-breaking scientific results and advancing technological exploitation. For the past five years, the QuantERA ERA-NET Cofund Programme has been successfully providing the research community with a coordinated Europe-wide approach to support cutting-edge research in QT. Building on this experience and with the European Union's support, the QuantERA Consortium continues its activities through mapping the development of QT public policies in Europe.

Launched in 2016, the QuantERA ERA-NET Cofund is currently the leading European network of public Research Funding Organisations (RFOs) for Quantum Technologies. QuantERA has managed to efficiently mobilise, coordinate and pool financial resources between regional, national and EU research programmes in the area of QT for funding ambitious research and innovation in jointly identified and selected topics of common interest. Its main goal is to stimulate and intensify research and innovation in the field of QT at the European level through a framework for funding transnational collaborative projects and, more broadly, supporting national and regional programmes for funding research in this field. Our framework contributes to the development of a coherent EU research strategy in the area of QT and, together with the Quantum Technologies Flagship, reinforces the European leadership on the world stage.

QuantERA answers the growing need for collaborative endeavours and a common funding scheme within QT research, which – due to its highly interdisciplinary nature – cannot be confined to an individual institution or state. Through coordination of national and regional research funding programmes, QuantERA avoids the problem of fragmentation of national efforts, encouraging transnational collaborations and leveraging Europe's competitive advantage.

Foreword

In the year 2009 I participated in the writing of an ERA-NET type initiative named CHIST-ERA. It consisted of a Consortium of 9 national organizations in Austria, France, Germany, Ireland, Italy, Poland, Spain, Switzerland and the United Kingdom, aimed at overcoming the fragmentation along national lines of long-term research in the field of Information and Communication Science and Technologies (ICST), and thus create synergy to amplify the activities of National Organizations; contribute decisively to the development of a concerted European scientific policy; and fulfil the needs and reinforce the strengths of the European ICST research community, so that it could be at the leading edge of world competition. The first call of this initiative was in the field of Quantum Information Foundation and Technologies, that was back then in what we could call its "teen" years, being born as a research theme in the late 90s.

It is from this former initiative that the QuantERA ERA-NET Cofund action was born in 2016, and has become the impressive initiative it is today, encompassing 32 organisations from 27 countries, which funded 38 transnational research projects in the (now mature) field of Quantum Technology, involving the staggering number of 193 research teams across the whole of Europe. QuantERA complements in an excellent fashion the activities of the Quantum Technology Flagship, and represents an important part of the fleet of activities that the European Commission is funding in this important area.

Therefore, it is with particularly great pleasure that I welcome this report, which describes the existing national public policies in Quantum Technology and provides a much-needed snapshot of the current Member States' involvement in this research area which will shape the future of the European industry and society.

Tommaso Calarco
Chair of the Quantum Community Network
Member of the QuantERA Strategic Advisory Board

Tommaso Calarco has pioneered the application of quantum optimal control methods to quantum computation and to many-body quantum systems. Currently the Director of the Institute for Quantum Control of the Peter Grünberg Institute at Forschungszentrum Jülich, Tommaso received his PhD at the University of Ferrara and started to work as a postdoc in the group of P. Zoller at the University of Innsbruck. He was appointed as a Senior Researcher at the BEC Centre in Trento in 2004 and as a Professor for Physics at the University of Ulm in 2007, where he then became Director of the Institute for Complex Quantum Systems and of the Centre for Integrated Quantum Science and Technology. In 2016 he authored the Quantum Manifesto, which launched the European Commission's Quantum Flagship initiative, and is currently the Chairman of one of the Flagship's Governing Bodies: The Quantum Community Network.

QuantERA Strategic Advisory Board

The QuantERA Strategic Advisory Board (SAB) consists of up to 12 prominent researchers from the fields of Quantum Technologies and representatives of industry. It provides advice on matters such as: the thematic scope of the QuantERA calls and potential future funding actions, the scientific aspects of QuantERA activities such as outreach or cooperation with non-European countries, new developments and issues related to research in QT that may have a strategic impact on the QuantERA programme's activities.

QuantERA SAB 2019-2021:

- Alain Aspect (Institut d'Optique)
- Stefanie Barz (University of Stuttgart)
- Tommaso Calarco (Research Centre Jülich)
- Nicolas Gisin (University of Geneva)
- Igor Jex (Czech Technical University in Prague)
- Peter L. Knight (Imperial College London)
- Gerd Leuchs (Max Planck Society)
- Yehuda Naveh (Classiq)
- Thorsten Schumm (Vienna University of Technology)
- Andrew Shields (Toshiba Research Labs Europe)
- Jiri Vala (Maynooth University)
- Marek Żukowski (Uniwersytet Gdański)

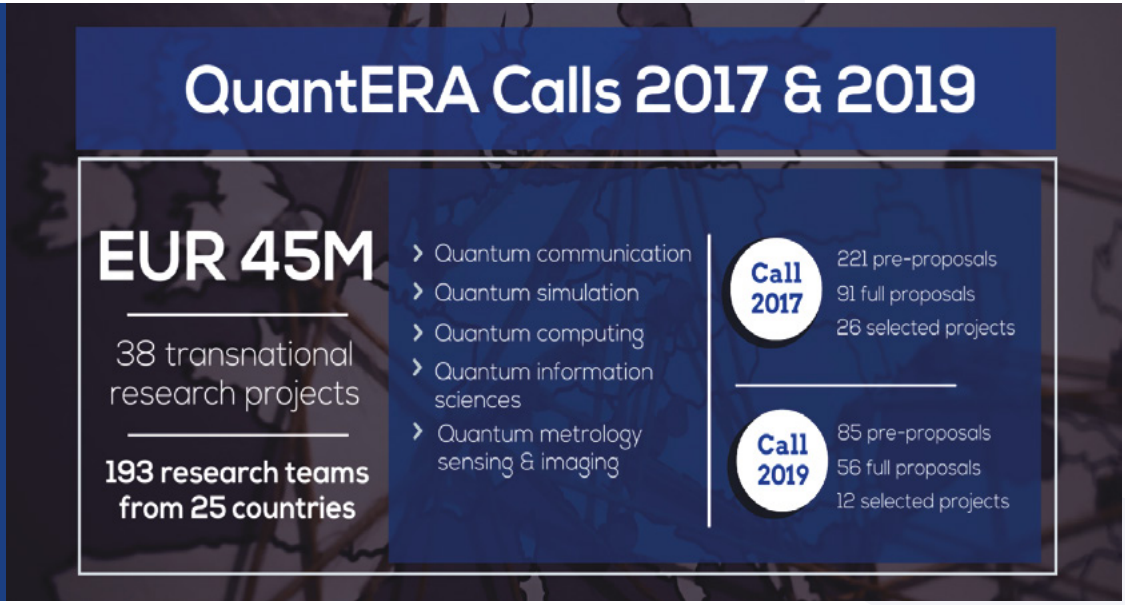
QuantERA at a glance

QuantERA is a network of Research Funding Organisations from European countries, coordinated by the National Science Centre, Poland, supporting international research projects in the field of Quantum Technologies (QT).

The central objective of the QuantERA programme was to launch a transnational co-funded call for proposals that would aim to contribute to further integration of European research in Quantum Technologies. In 2019, following the success of the 2017 co-funded call, the consortium managed to significantly surpass the initial goals and gathered a substantial pool of national and regional funds that permitted embarking upon the mission to initiate the second call for proposals without EC funding. So far, QuantERA has successfully launched two calls for proposals attracting over 1500 research teams to apply, with more than 4500 individual researchers from all over the world.

QuantERA has funded 38 excellent transnational projects for over €45 million, bringing together 193 research teams from 25 countries and gradually increasing Europe's competitive advantage in the field of QT. The funded research aims to develop novel physical platforms for quantum communication, sensing and computing, advance architectures and algorithms for future quantum information processing systems, and push for hardware scalability. The results from the funded projects are expected to address several societal challenges, such as cybersecurity and healthcare.

The launch of the call for proposals was complemented by a range of additional activities aimed at stimulating cooperation within the research community, creating and maintaining links between academia and industry, building a toolkit on responsible research and innovation in QT, exchanging best practices and engaging in a dialogue with policy makers about the design of future funding instruments. Altogether, this assists in taking further steps along the road to unlocking the widely recognised industrial potential of QT in response to current societal needs and for the benefit of the public at large.



About this report

In summer 2020, members of the QuantERA Consortium set out to describe the existing national public policies in Quantum Technologies. Each organisation considered the state of affairs within their respective country with regard to the following:

- Funding instruments of the organisation;
- Research priority areas in Quantum Technology;
- Quantum Technology funding within the organisation;
- Quantum Technology funding at the national level;
- National Quantum Technology research community.

The above information was collated in the form of a factsheet, summarising the efforts in Quantum Technology research and funding at the organisation and national level. This report is the collaborative product of that process.

The results of the following inventory should contribute to inform researchers on public policies in Quantum Technologies in Europe, as well as the funding instruments and priorities within the relevant RFOs. Moreover, it should support the coordination of those public policies between the RFOs, the advancement of the QuantERA programme and of future transnational QuantERA calls for proposals, and the further development of the European Quantum Technology Flagship.

This report has been elaborated as part of the Task 6.5, *'Mapping the development of public policies in QT in Europe and worldwide'* within the Work Package of QuantERA (Strategic Developments – additional activities), a vast international ERA-NET project that has received funding from the European Union's Horizon 2020 Research and Innovation Framework Programme under Grant Agreement No. 731473.

Country factsheets

Executive summary

Funding instruments

The majority of the QuantERA partners fund Quantum Technology research through regular national (and/or regional) bottom-up open calls or programmes. Those calls are usually open to all scientific domains, with no restrictions on themes, inviting individual researchers and research organisations. Some of the Research Funding Organisations (RFOs) have also launched specific open programmes for career development and early stage researchers, in which researchers in the quantum domain need to compete with researchers from other domains. As QT research is still a relatively new topic of discussion for many governments, the dialogue between the stakeholders is ongoing, and the social, ethical and legal parameters are still yet to be developed in a lot of European countries. For those funding agencies that are not able to liaise with specific QT initiatives at a national level, QuantERA is the crucial funding instrument through which specific funding to QT research can be allocated. By bringing together the national funding and EU top-up, QuantERA plays an instrumental role in enabling the creation of a pan-European funding programme devised specifically for QT research.

In addition to the Quantum Technologies funding support given by the EU, various individual Member States and Associated Countries – including Austria, Germany, Hungary, Israel, the Netherlands, Switzerland and the United Kingdom – have introduced their own national thematic calls or programmes to fund QT research and innovation. Those pioneering initiatives that support national investment in QT research and development play a major role in both intensifying international competition and creating opportunities for cooperation, propelling the major push to develop Quantum Technologies within Europe.

Research priority areas

Most of QuantERA RFOs funding research through open bottom-up calls do not define any specific priority areas in their recommendations, rather focusing on creating opportunities for researchers and experts. On the other hand, those RFOs using thematic calls or programmes have indeed identified priority areas in the QT domain, however these priorities vary among the regions. The table below outlines these differences. Note that the subfields of Quantum Technologies are broadly understood in accordance with definitions used in QuantERA Calls.

	Austria	Germany	Ireland	Israel	Italy	Netherlands	Switzerland	United Kingdom
Quantum communication	√	√			√			√
Quantum cryptography		√						
Quantum computing and simulation	√	√		√	√	√	√	√
Quantum information sciences	√		√				√	
Quantum metrology, sensing and imaging	√	√	√	√	√	√		√
QT for energy and environment					√			
Quantum infrastructures					√			
QT education and training					√			
Basic technologies for quantum systems					√			

Table 1. Summary of research priority areas in countries with dedicated national QT programmes

The Quantum Technology domain is extremely complex, and its development is a mammoth – nonetheless pivotal – international endeavour. European countries recognise Quantum Technologies as both an ambitious and an attractive venture, and those who have identified specific priority areas within this crucial domain of research are leading the way and setting an example within the evolving European quantum landscape.

Funding Quantum Technologies

Investment in Quantum Technologies greatly varies among the EU Member States and Associated Countries, and within the Research Funding Organisations, the budgets dedicated to the QT calls for proposals range from less than €1 million to over €10 million. Within the QuantERA consortium, for most of the participating RFOs, the budget for the QuantERA calls (both co-funded by the EU and launched without EU funding) is a substantial part of the overall QT budget. Only five QuantERA RFOs: FFG, BMBF/VDI TZ, ISERD, NWO and UKRI, have a dedicated yearly budget of over €10 million set up for specific quantum programmes.

It is important to note, however, that the amounts are not comparable across the countries – as different regions decide to fund varying aspects of research projects. Budgets are often dedicated for hiring PhD students and/or postdocs, buying or hiring specific equipment as well as renting facilities – permanent staff salaries and specific quantum infrastructures are seldom included.

Since its launch in November 2016, the QuantERA programme, bringing together an international consortium of RFOs, has funded a multitude of projects focused on fundamental QT research, proving to be an unprecedented success. The programme enabled the launch of two transnational calls for proposals so far, thus pooling circa €45 million of national/regional commitment and €11,5 million of EC co-funding towards QT research and innovation.

National QT programmes

In addition to the QT funding from the EU, a number of QuantERA partners are involved in national programmes targeting Quantum Technologies with an important focus on innovation-oriented research. A few of the programmes warrant particular attention, not only because of their pioneering role, but most of all because of their crucial function in reinforcing Europe's position in the field of Quantum Technology.

Austria

The Austrian **Quantum science and technology** (QFTE) programme is run by FFG in cooperation with FWF. The aim of this programme is to bring knowledge from basic quantum physics research closer to technological application. Research organisations and research-active companies in QT are supported in order to strengthen the international competitiveness of Austria as a location through thematic leadership. National and transnational calls are regularly offered with funding instruments such as Cooperative R&D Projects. The total annual call budget is €2-5 million.

Germany

In 2018, the German Federal Government launched the multi-annual framework programme **Quantentechnologien – von den Grundlagen zum Markt (Quantum Technologies – from basic research to market)**, which is implemented under the auspices of the BMBF (Federal Ministry of Education and Research) and operationally supported by

Country	Dedicated national QT programme
Austria	Quantum Science and Technology (QFTE) programme[1]
Germany	Quantum Technologies – from basic research to market programme[2]
Hungary	HunQuTech programme[3]
Israel	Israel National Quantum Initiative (INQI)
Italy	QT represented within the *National Research Plan*
Netherlands	National Agenda for Quantum Technology[4]
Sweden	Wallenberg Centre for Quantum Technology (WACQT)[5]
Switzerland	Quantum Science and Technology (NCCR-QSIT) programme[6]
United Kingdom	UK National Quantum Programme[7]

Table 2. Dedicated national QT programmes

1. https://www.ffg.at/quantenforschung-und-technologie
2. https://www.quantentechnologien.de/fileadmin/public/Redaktion/Dokumente/PDF/Publikationen/Federal-Government-Framework-Programme-Quantum-technologies-2018-bf-C1.pdf
3. https://wigner.hu/quantumtechnology/en
4. https://www.tno.nl/en/about-tno/news/2019/9/national-agenda-quantum-technology-from-academic-knowledge-to-applications/
5. https://www.chalmers.se/en/centres/wacqt/about%20us/Pages/default.aspx
6. http://www.snf.ch/en/researchinFocus/nccr/nccr-qsit/Pages/default.aspx
7. https://uknqt.epsrc.ac.uk

QuantERA partner VDI TZ. The Federal Government announced it would provide funds of approximately €650 million between 2018 and 2022 (the entire duration of the programme).

Hungary

The Hungarian **HunQuTech** is a four-year (2017-2021) National Quantum Technologies Programme from the National Research, Development and Innovation Office, offering €11 million funding for Quantum Technologies research and development. Funded within the National Excellence Programme (NKP_17), it brings together outstanding research groups in Hungary, as well as a number of industrial partners. The strategic research agenda is defined by the consortium implementing the programme and is aligned with the European Quantum Technologies Flagship.

Israel

The **Israel National Quantum Initiative (INQI)** is a joint venture of the leading R&D funding agencies in Israel. These include the Council for Higher Education, the Israel Innovation Authority (under which ISERD is the agency in charge of R&D relations with the EC framework – the MFF), the Ministry of Science, the Ministry of Defence and the Ministry of Finance. These agencies all cooperate in INQI, which is headed by a small executive body in charge of coordination. The overall budget frame of the programme is approximately €325 million over circa 5 years.

Sweden

In Sweden, the 12 year 1 billion SEK research programme – the **Wallenberg Centre for Quantum Technology** aims to take Swedish research and industry to the forefront of quantum technology. Through an extensive research programme, the focus lies in developing and securing Swedish expertise within the main areas of quantum technology: quantum computing and simulation, quantum communications and quantum sensing. The main project is to develop a high-end quantum computer that can solve problems far beyond the reach of the best conventional supercomputers.

Switzerland

The Swiss SNSF has created **QSIT – Quantum Science and Technology** as one of the National Centres of Competence in Research (NCCRs). Its goals range from present and future engineering applications, such as quantum cryptography and quantum computation, to the investigation of new paradigms for fundamental physics such as topological states of matter.

United Kingdom

During the first phase of the **UK National Quantum Technologies Programme** (2014 – 2019), EPSRC funded a national network of Quantum Technology Hubs through a £120 million investment in four hubs over five years. These were to harness the UK's strengths in quantum science by turning this into strength in Quantum Technologies. As part of their investments in the second phase of the National Programme, EPSRC has refreshed the Quantum Technology Hubs at the end of 2019, with a £94 million investment in four hubs over five years, to maintain the technological research leadership that the UK has established in Quantum Technologies.

The vastness of the QT research field means that it often exceeds the region's capacity to accelerate the process of introducing QT to the market and society. Individual countries alone cannot develop Quantum Technology and the associated market, therefore, active collaboration and cohesive planning on a larger scale is necessary to obtain common success. Given the commitment from the EU to develop the QT infrastructure, research funding through the QuantERA programme is often the only way to help the participating RFOs to set things in motion and push QT research up the international agenda.

Quantum Technologies Flagship Fleet

Over the past five years, and with the support of the QuantERA programme, the international dialogue regarding QT has not only developed, but undoubtedly taken wing. International communication within the QT community is the vital step in establishing and propelling growth in the research field. In this report, we have included the descriptions of QT research communities in different countries. On the pan-European level, the community is well organised through the establishment of the Quantum Technologies Flagship and the Quantum Community Network (QCN), representing the QT communities of EU Member States and Associated Countries.

The **Quantum Technologies Flagship** is a large-scale undertaking with an expected 10-year timeline and a planned budget of €1 billion. Driven by an ambitious vision, it consists of a coherent set of research and innovation projects selected through a thorough peer-review process. The programme was launched by the EU in 2017, following the publication of the Quantum Manifesto[8]. Future and Emerging Technologies (FET) Flagships[9], being programmes formed within H2020 framework, are vast research initiatives investing in transformative frontier research and innovation with a high potential impact on technology, to benefit our economy and society.

The **Quantum Community Network (QCN)** was established in order to be able to appropriately and actively engage the large number of stakeholders in Europe. Composed of distinguished members of the QT community, who have agreed to commit to liaising with their national stakeholders to collect and share information about best practices on QT-relevant activities in their respective countries, the QCN helps coordinate the interaction between the QT Flagship and the national initiatives. The core objective of the QCN is alignment of the national programmes with the aims of the QT Flagship.

Around the world, billions of Euros are being invested in the development of Quantum Technologies both through coordinated continental scale programmes and by individual countries. Recognising this incredible investment opportunity not only drives the competition on a global scale but, most importantly, also attracts talented and experienced researchers to be a part of this extraordinary undertaking. Strengthening and maintaining QT research communities, like the QCN, leads to accelerating research and innovation, and generating valuable input that helps put QT research in Europe in the limelight.

8. https://qt.eu/app/uploads/2018/04/93056_Quantum-Manifesto_WEB.pdf
9. https://ec.europa.eu/digital-single-market/en/fet-flagships

National funding in Quantum Technologies – overview

Country	Research Funding Organisation	QuantERA 2017 Call funding allocation	QuantERA 2019 Call funding allocation	Main QT funding instrument	National QT budget per year
Austria	FWF	€500 000	€1 000 000	Open bottom-up national calls	€10-30 million
Austria	FFG	€500 000	€1 500 000	Thematic calls/programmes	
Belgium	FWO	€1 500 000	N/A	Open bottom-up regional calls	€2-5 million
Belgium	F.R.S.-FNRS	€200 000	€200 000	Open bottom-up regional calls	
Bulgaria	BSBF	€300 000	€300 000	Open bottom-up national calls	< €1 million
Croatia	HRZZ	N/A	€200 000	Open bottom-up national calls	< €1 million
Czech Republic	MEYS	€200 000	€500 000	Participation in QuantERA	< €1 million
Denmark	IFD	€1 000 000	€500 000	National open calls complemented by international calls	€2-5 million
Finland	AKA	€700 000	N/A	Open bottom-up national calls	€5-10 million
France	ANR	€2 500 000	€2 500 000	National open calls complemented by international calls	€5-10 million
Germany	BMBF/ VDI TZ	€4 000 000	€2 000 000	Thematic calls complemented by open calls	€20-30 million
Greece	GSRT	€400 000	€1 000 000	Thematic bilateral call	€2-5 million
Hungary	NKFIH	€300 000	€300 000	Both: Bottom-up Calls; thematic calls/programmes	€2-5 million
Ireland	SFI	€500 000	N/A	Open bottom-up national calls	€2-5 million
Israel	ISRED	€500 000	€500 000	Thematic calls/programmes	> €50 million
Italy	CNR	€1 500 000	€400 000	National open calls complemented by international calls	€2-5 million
Italy	MUR	€400 000	N/A	National open calls complemented by international calls	€2-5 million
Lithuania	LMT	N/A	€100 000	Open bottom-up national calls	< €1 million
Latvia	VIAA	€400 000	€420 000	Participation in QuantERA	< €1 million
Netherlands	NWO	€1 000 000	N/A	Open bottom-up national calls	€10-30 million
Norway	RCN	€500 000	€500 000	Open bottom-up national calls; thematic calls/programmes	€2-5 million
Poland	NCN	€1 000 000	€1 000 000	Open bottom-up national calls	€2-5 million
Poland	NCBR	€500 000	€600 000	Thematic calls/programmes	
Portugal	FCT	€250 000	€250 000	Open bottom-up national calls	< €1 million
Romania	UEFISCDI	€600 000	€600 000	Open bottom-up national calls	< €1 million
Slovakia	SAS	€240 000	€120 000	Participation in QuantERA	< €1 million
Slovenia	MIZS	€300 000	€300 000	Open bottom-up national calls	< €1 million
Spain	AEI	€500 000	€500 000	Open bottom-up national calls	€5-10 million
Sweden	VR	€1 000 000	€630 000	Open bottom-up national calls	€5-10 million
Switzerland	SNSF	€1 000 000	€1 000 000	Both: Bottom-up Calls; thematic calls/programmes	€5-10 million
Turkey	TUBITAK	€400 000	€1 500 000	Open bottom-up national calls	€2-5 million
United Kingdom	UKRI	€2 300 000	€1 120 000	Thematic calls/programmes	> €50 million

Table 3. Overview of the survey carried out in Summer 2020, asking all QuantERA RFOs to summarise their national funding in QT.

AUSTRIA

Österreichische Forschungsförderungsgesellschaft: Austrian Research Promotion Agency (FFG)

Funding instruments

The Austrian Research Promotion Agency (FFG) is the national funding agency for industrial research and development in Austria. FFG funds applied quantum research through a thematic programme "Quantum science and technology". In addition, quantum research projects can be submitted to the open programme "General Programme".

The national quantum programme "Quantum science and technology" (QFTE)[10] is run by FFG in cooperation with FWF. The aim of this programme is to bring knowledge from basic quantum physics research closer to technological application. Research organisations and research-active companies in QT are supported in order to strengthen the international competitiveness of Austria as a location through thematic leadership.

National and transnational calls are regularly offered with funding instruments such as Cooperative R&D Projects. The total annual call budget is €2-5 million. The national programme QFTE was evaluated in 2019 by Technopolis[11]. The result of the evaluation showed that all four thematic areas of the QT Flagship are relevant for Austria. Transnational cooperation within Europe was generally encouraged and further participation in QuantERA II was strongly recommended by this evaluation.

The funding strategy of "General Programme"[12] is fundamentally based on the bottom-up principle. It is open to all branches of industry and research topics and eligible to companies and projects of all sizes. The programme aims to strengthen the competitiveness of companies based in Austria by funding the development of new products, processes and services. For this funding programme FFG uses a combination of several financing instruments such as grants as well as low-interest loans.

Research priority areas in Quantum Technology

National and transnational QFTE calls are open to all areas in Quantum Technologies. No thematic priorities are defined.

Quantum Technology funding within organisation

In 2018, the national funding programme QFTE was initiated and is run by FFG and FWF. National joint calls are launched once a year covering all five areas in Quantum Technologies (Quantum communication, Quantum simulation, Quantum computation, Quantum information sciences, Quantum metrology, sensing and imaging). There is no priority among the areas.

Quantum Technology funding at national level

In Austria, besides FFG, the only other major public funding body in QT research is the FWF[13], which mainly supports basic research.

10. https://www.ffg.at/quantenforschung-und-technologie
11. https://repository.fteval.at/388/
12. https://www.ffg.at/en/programme/general-programme
13. https://www.fwf.ac.at/en/

National Quantum Technology research community

Austria has been a leading country in quantum science and technology research since the early 1990s. Out of initial quantum optics activities by groups at the University of Innsbruck and the Technical University of Vienna, which engaged in theory and experiments on photons, trapped ions and neutrons, a sizeable research community, distributed over Innsbruck, Linz and Vienna that works on various directions in quantum science and several implementations of quantum technologies. The areas covered include theory and experiments on quantum computation and simulation with trapped ions, neutral atoms, superconducting qubits and photons, quantum communication via free space and optical fibres, including interfaces to atomic and solid state systems, and quantum sensing with atoms, ions, colour centres and optomechanical systems. While the majority of these activities are carried out in academic settings, industrial players have become involved and several startup companies have recently formed. The four main research institutions in quantum science and technology in Austria collaborate within the Erwin Schrödinger Centre for Quantum Science and Technology (ESQ), which currently includes 40 faculty members.

Contact information

QuantERA

Fabienne Nikowitz
Fabienne.Nikowitz@ffg.at

Quantum Community Network

Gregor Weihs
Gregor.Weihs@uibk.ac.at

Markus Aspelmeyer
Markus.Aspelmeyer@univie.ac.at

Fonds zur Förderung der Wissenschaftlichen Forschung: Austrian Science Fund (FWF)

FWF Der Wissenschaftsfonds.

Funding instruments

The Austrian Science Fund FWF is the most important Austrian funding organisation for all disciplines of basic research (i.e. for the gaining of scientific knowledge). The FWF supports research in science, engineering and the humanities through a large variety of grant programmes, prizes and fellowships. The programmes are open to all scientific domains, with no restrictions to the theme. Thus, the programmes offered by the FWF are, in general, of a bottom-up nature. Funding for Quantum Technology (QT) comes from successful project proposals submitted to different programmes and calls.

The thematic programme QFTE is an exception to this general bottom-up nature of FWF programmes. This programme has been run since 2018 together with the Austrian Research Promotion Agency (FFG) in the form of national and transnational calls targeting research projects in QT. The aim of QFTE is to bring knowledge from basic quantum physics research closer to technological application, although the research still focuses on the gaining of scientific knowledge. Nevertheless, the largest part of QT funding by FWF is spent via bottom-up programmes.

Each year, FWF compiles a list of funded QT research projects to enable an overview of how much budget is acquired by this research area. But because most of the funding is run via bottom-up programmes, there has not been any portfolio analysis or foresight exercise done with respect to QT in the FWF. Nevertheless, the QFTE programme has been evaluated by an online survey among QT researchers in 2019, which has led to a substantial reshaping of the subsequent FWF QFTE call. The FFG, with which the FWF is collaborating in the QFTE programme, did its own evaluation of the programme.

The FWF has a few programmes that are aimed at young scientists. The START programme[14] is aimed at outstanding researchers with a maximum of eight years of postdoc experience. The Firnberg[15] and Richter[16] fellowships are aimed at young female scientists, without a definite maximum of postdoc experience. All these programmes are open for all scientific disciplines, without special regard to QT.

Research priority areas in Quantum Technology

The FWF has not defined any priority areas in QT. There is also no national strategic research agenda for QT. Funding comes from the success of the researchers in the different calls based on the quality of their project proposals.

Quantum Technology funding within organisation

An estimate of the financial support of projects related to QT has been done by selecting the projects from the FWF database. Between 2015 and 2018, the FWF has funded projects related to the QT field with about €46 million (~€11.5 million/year). This estimate does not include salaries of permanent staff involved in the research projects.

No increase of public funding for QT is planned in the next three years.

Quantum Technology Programmes

FFG and FWF jointly run the Quantum Research and Technology (QFTE) programme, see above. The programme has run since 2018 with a total annual budget of €2-5 million. National joint calls are launched once a year covering all areas of QT (quantum communication, quantum simulation, quantum computation, quantum information sciences, quantum metrology, sensing and imaging) without any priority among the areas.

There are currently no plans for new programmes in QT research.

14. https://www.fwf.ac.at/en/research-funding/fwf-programmes/start-programme/
15. https://www.fwf.ac.at/en/research-funding/fwf-programmes/firnberg-programme/
16. https://www.fwf.ac.at/en/research-funding/fwf-programmes/richter-programme-incl-richter-peek/

Quantum Technology funding at national level

Besides FWF, the only other major public funding body in QT research is the Austrian Research Promotion Agency (FFG) which mainly supports applied research.

National Quantum Technology research community

Austria has been a leading country in quantum science and technology research since the early 1990s. Out of initial quantum optics activities by groups at the University of Innsbruck and the Technical University of Vienna, which engaged in theory and experiments on photons, trapped ions and neutrons, a sizeable research community developed, distributed over Innsbruck, Linz and Vienna that works on various directions in quantum science and several implementations of quantum technologies. The areas covered include theory and experiments on quantum computation and simulation with trapped ions, neutral atoms, superconducting qubits and photons, quantum communication via free space and optical fibres, including interfaces to atomic and solid state systems, and quantum sensing with atoms, ions, colour centres and optomechanical systems. While the majority of these activities are carried out in academic settings, industrial players have become involved and several startup companies have recently formed. The four main research institutions in quantum science and technology in Austria collaborate within the Erwin Schrödinger Centre for Quantum Science and Technology (ESQ), which currently includes 40 faculty members.

Contact information

QuantERA

Stefan Uttenthaler
Stefan.Uttenthaler@fwf.ac.at

Quantum Community Network

Gregor Weihs
Gregor.Weihs@uibk.ac.at

Markus Aspelmeyer
Markus.Aspelmeyer@univie.ac.at

BELGIUM

Fonds voor Wetenschappelijk Onderzoek – Vlaanderen: Research Foundation Flanders (FWO)

Funding instruments

The Research Foundation – Flanders (FWO) supports fundamental and strategic scientific research, stimulates international cooperation and promotes equal opportunity.

Quantum Technologies research is funded through regional open calls/programmes. The calls are open to all scientific domains, with no restrictions on theme.

Research priority areas in Quantum Technology

The FWO is a non-thematic, bottom-up funder. All areas in the QT domain are considered as high priority areas and between the different QT domains no priorities have been defined.

Additionally, there is no national or regional research agenda for Quantum Technologies, defining priority areas in QT technologies.

Quantum Technology funding within organisation

There is no specific information available on the funding into Quantum Technologies within FWO. It is not known if funding for Quantum Technology will be increased in the coming years.

Quantum Technology funding at national level

Other funding bodies supporting research projects related to the areas of QT are: VLAIO, innovation oriented research for the Flemish speaking community; FNRS, fundamental scientific research for the French speaking research community; SPW, innovation-oriented research for the French speaking community; and Innoviris for the Brussels region.

Contact information

QuantERA

Toon Monbaliu
eranet@fwo.be

Quantum Community Network

Milos Nesladek
Milos.Nesladek@uhasselt.be

Fonds de la Recherche Scientifique: Fund for Scientific Research (F.R.S.-FNRS)

Funding instruments

The Fund for Scientific Research – FNRS (F.R.S.-FNRS) is funding Quantum research through open calls/programmes. Being a bottom-up basic research-funding agency, the F.R.S.-FNRS's calls are open to all scientific domains, with no restrictions on research area. The F.R.S.-FNRS funds research that is performed in public research institutions of the French-speaking community of Belgium.

The F.R.S.-FNRS supports individual researchers and projects based on the criterion of excellence. The F.R.S.-FNRS supports:

- Temporary individual mandates: fellowships for doctoral students and post-doctoral internships;
- Permanent individual mandates from starting positions (Research Associate) to senior positions (Senior Research Associate and Research Director);
- Research projects: small scale 2-year projects (operating and small equipment costs) or bigger scale 4-year projects (personnel, operating and small equipment costs);
- Equipment projects: funds allocated for the purchase of large equipment;
- Grants and credits for international collaboration: participation in joint programming (QuantERA, for example) and bilateral research calls; and
- Scientific prizes.

All the calls and programmes are bottom-up. There are no specific instruments to support Quantum Technology topics. QT funding comes from the success of the researchers in the different calls based on the quality of the projects.

Research priority areas in Quantum Technology

The national calls are open to all scientific domains, with no priority areas defined.

Quantum Technology funding within organisation

Research proposals

Between 2017 and the first semester of 2020, the F.R.S.-FNRS received **103 research project proposals** identified as being related to "Quantum Technologies" out of a total 7650 research project proposals (1.3%).

2017	2018	2019	2020
29	18	38	18

Table 4. Number of research project proposals associated with Quantum Technologies

Awarded research projects

The F.R.S.-FNRS has awarded 41 research projects out of a total 2250 awarded research projects (1.8%).

2017	2018	2019	2020
11	6	17	7

Table 5. Number of awarded research projects associated with Quantum Technologies

The total budget awarded to Quantum Technology research projects between 2017 and the first semester of 2020 is estimated at **€6 730 935.5.** The total budget of awarded research projects for the same period is €476 010 680.2 (1.4%).

2017	2018	2019	2020
1 959 339.5	930 536.1	2 783 960.0	1 057 100.0

Table 6. Total budget awarded to research projects associated with Quantum Technologies

Mandates

The F.R.S.-FNRS funds permanent individual mandates from starting positions (Research Associate) to senior positions (Senior Research Associate and Research Director).

As of January 2020, the F.R.S.-FNRS funds 24 permanent researchers working in the Quantum Technology field out of 394 permanent researchers (6%).

Research Associate	Senior Research Associate	Research Director
16	4	8

Table 7. Number of permanent representatives of the F.R.S.-FNRS on 01/01/2020 being associated with Quantum Technologies on 01/01/2020, by type of mandatee

Quantum Technology Programmes

The F.R.S.-FNRS does not have a specific Quantum Programme. Quantum research is supported through participation in the QuantERA network and through the annual calls (open to all topics) that the F.R.S.-FNRS organizes.

Contact information

QuantERA

Florence Quist
Florence.Quist@frs-fnrs.be

Quantum Community Network

Milos Nesladek
Milos.Nesladek@uhasselt.be

BULGARIA

ФОНД НАУЧНИ ИЗСЛЕДВАНИЯ:
Bulgarian National Science Fund (BSBF)

Funding instruments
Quantum Technology research is funded through regular calls for fundamental research projects or national programmes (bottom-up). There are no specific programmes related to Quantum Technologies, except QuantERA.

Research priority areas in Quantum Technology
There are no specific priorities areas related to Quantum Technologies. BSBF has no strategic research agenda for Quantum Technologies.

Quantum Technology funding within organisation
The estimated funding into Quantum Technologies per year is <€1 million. No increase is expected in the next three years.

Quantum Technology Programmes
There is no dedicated funding programme for Quantum Technology within BSBF. No upcoming programme is expected in the next three years.

Quantum Technology funding at national level
There are no other public bodies supporting specifically projects related to Quantum Technologies

National quantum technology research community
BSBF has not collected information on the characteristics of the Quantum Research community in Bulgaria.

Contact information

QuantERA
Boriana Hadjieva
B.Hadjieva@mon.bg

Quantum Community Network
Nikolay Vitanov
Vitanov@phys.uni-sofia.bg

CROATIA

Hrvatska Zaklada za Znanost: Croatian Science Foundation (HRZZ)

Funding instruments

The Croatian Science Foundation (HRZZ) funds quantum research through a national open calls programme. The national calls are open to all scientific domains, with no restrictions on the theme. The calls are bottom-up. The applicant can submit a project proposal only in the area for which the scientific organisation in which he/she is employed and where the project will be implemented has been accredited. There are three types of research programme: The "Installation Projects" programme supports the development of individual research careers of young scientists and new research teams that address internationally recognised and nationally relevant topics. The "Research Projects" programme has been established for funding fundamental research whose goal is creating new and enhancing existing knowledge about a specific area and that is directed at better understanding of the research topic as well as applied research that is conducted with clear technological, economic or social aims in mind. The "Partnership in Research" programme is intended to support partnerships in research between public universities or public scientific institutes in Croatia or extra-budgetary sources of funding (not funded from the State budget) from Croatia or from abroad (private companies, local administration units, foreign foundations and agencies for funding research, foreign scientific organisations). Furthermore, HRZZ has a dedicated programme, "Young Researchers' Career Development Project – Training New Doctoral Students", whose goal is fostering young researchers in the early phase of their career development (at postgraduate level) in the science and higher education system. Doctoral students' salaries are funded, divided into two periods, each with a duration of two years. The first period includes doctoral studies and registration of the doctoral thesis. A positive evaluation of the achieved results is a precondition to continuing funding for the next two years, during which the young scientist will finalise their doctoral thesis. The final aim is producing a doctoral dissertation and adopting knowledge regarding basic postulates of scientific work and research.

Research priority areas in Quantum Technology

There is no national or regional strategy including Quantum Technologies.

Quantum Technology funding within organisation

Within the HRZZ database, there are 14 individual Installation and Research Projects related to Quantum technologies that have been implemented from the period since 2015 with approximately €2 million, including the salaries of doctoral students funded through the programme "Young Researchers' Career Development Project – Training New Doctoral Students".

Quantum Technology Programmes

There is no dedicated funding programme for Quantum Technology within HRZZ. No upcoming programme is expected in the next three years.

Quantum Technology funding at national level

In Croatia, there is no national program focused on Quantum Technologies. However, a rich variety of research in the field of Quantum Technologies is financed through various projects and programmes conducted in scientific centres of excellence and infrastructure projects that are funded by the EU and supported by the Republic of Croatia.

The Centre for Advanced Laser Techniques – CALT[17], is a research infrastructure project of the Institute of Physics that is included in the Croatian Research and Innovation Infrastructures Roadmap and was declared in March 2017 as a project of strategic importance for the Republic of Croatia. The main goal of the project is to improve, upgrade and develop new research infrastructure based on advanced laser techniques at the Institute of Physics. CALT's mission is to provide an environment for interdisciplinary laser-based research at the highest level.

17. http://calt.ifs.hr/en/

The Cryogenic centre at the Institute of Physics (KaCIF) project[18], has as its main goal the upgrading of existing and developing of new low temperature techniques, as well as the modernization and upgrading of scientific research equipment used in fundamental and applied research in condensed matter physics.

The Scientific Centre of Excellence for Quantum and Complex Systems, and Representations of Lie Algebras (QuantiXLie)[19], concentrates on strongly reinforcing the international visibility of theoretical physics and mathematics research conducted at Croatian universities and scientific institutes, and to enable the implementation of large competitive projects for international programmes.

QuantiXLie aims to create a motivating environment for learning and training of young researchers and provide a stable long-term financial framework for their education and professional development.

The Centre of Excellence for Advanced Materials and Sensing Devices (CEMS)[20], has a strong research line in photonics and quantum optics, including: quantum communication, quantum entanglement, random number generation, quantum contextuality, quantum-assisted bio-mimetic computing, quantum sensors and quantum repeaters. Another objective of the Centre is the synthesis of advanced materials and structures, particularly those that can be applied in other domains of basic and applied science, thus catalysing innovation, transfer of technologies and enhancing capabilities in instrumentation and human resources.

National quantum technology research community

There are several research groups working in the field of QT[21]:

1) Institute of Physics, Zagreb (Research topic: Cold atoms). The group investigates cold atoms, cooled and trapped in magneto-optical traps by laser cooling techniques including novel phenomena that arise when the mechanical action on cold atoms is induced by frequency comb (FC) excitation.
2) University of Zagreb (Atomic gases/optics and photonics). The group investigates topics in ultracold atomic gases including anions, topological phases, strongly correlated many-body systems, dynamics as well as topological photonics and nonlinear phenomena.
3) Ruđer Bošković Institute (Quantum information, Quantum entanglement, Quantum cryptography, Randomness, Information security, Quantum and Quantum-assisted computing). The group plans to build components for quantum communication for metropolitan-sized quantum networks.
4) Institute of Physics, Zagreb (Photonics, interferometry, holography). The research combines the development and application of digital holography and interferometry-based systems with investigation of fundamental quantum phenomena such as entanglement and quantum contextuality.
5) Institute of Physics, Zagreb (Disordered quantum systems, localization phenomena). The group investigates disordered quantum models by field theoretical methods and aims to understand the underlying mathematical structures of the theories describing phase transitions of such models.
6) Institute of Physics, Zagreb (Ultrafast laser spectroscopy). The research is focused on investigation of photochemical and other photo-induced processes using ultrafast spectroscopy methods.
7) Institute of Physics, Zagreb (Quantum magnets). The group investigates quantum information in the form of spins and electric dipoles found in novel materials, including magnets with constrained dimensionality, magneto electrics and multiferroics.
8) Institute of Physics, Zagreb (2D Materials). The scientific focus is on graphene and follow-up 2D materials which complement graphene and extend versatility regarding physical and chemical properties and related applications.
9) University of Split (Ultracold atoms/quantum fluids). The group investigates topics in ultracold atoms and quantum fluids including self-bound droplets, effects of confinement and disorder on strongly-correlated many body systems, spin-orbit coupled bosons and quantum halo states.
10) University of Rijeka (Optomechanics). The group is focused on the construction of a high sensitivity displacement/force sensors to be used in fundamental research.

18. http://kacif.ifs.hr/en/about-project/
19. http://bela.phy.hr/quantixlie/
20. http://cems.irb.hr/en/
21. http://croqt.ifs.hr/activities/events/

Contact information

QuantERA

Jasminka Boljević
Jasminka@hrzz.hr

Quantum Community Network

Ticijana Ban
Ticijana@ifs.hr

CZECH REPUBLIC

Ministerstvo školství, mládeže a tělovýchovy: The Ministry of Education, Youth and Sports (MEYS)

Funding instruments

The Ministry of Education, Youth and Sports of the Czech Republic (MEYS) supports research in Quantum Technologies via its involvement in the QuantERA ERA-NET Cofund in Quantum Technologies Programme as a National Funding Authority. The MEYS has been involved in all calls in QuantERA so far, and can fund both basic and applied research in Quantum Technologies. Furthermore, the MEYS provides institutional support to public universities and public research institutions for, among others, long-term development, basic and applied research and technology transfer on a non-discriminatory basis, therefore, research in quantum technologies can be financed from this support if the subjects concerned see fit.

The MEYS does not offer any funding programmes that promote young scientists exclusively; it has funding programmes open to everyone without prejudice to age or length of career. However, other national funding providers (such as the Czech Science Foundation) do have programmes dedicated specifically to young scientists. The programmes are not dedicated to any scientific discipline and the topic of the project is decided by the applicant. Therefore, Quantum Technology topics can also be present, but this is not necessarily the case as the programmes work on a bottom-up principle. The MEYS does not have any specific instrument for funding research in Quantum Technologies aside from its participation in the QuantERA consortium.

Research priority areas in Quantum Technology

The priority areas in Quantum Technology have not been identified. The MEYS supported the successful project proposals in the QuantERA programme based on the criterion of excellence and neither limited nor prioritized the funding of any stream of research in Quantum Technologies. The MEYS has no strategic research agenda for Quantum Technologies. However, it can be mentioned that bottom-up priorities identified by various Czech research teams active in the field of Quantum Technologies include, e.g. quantum communication, quantum cryptography, quantum information processing, quantum information science and quantum metrology and sensing.

Quantum Technology funding within organisation

As there are no specific calls for project proposals launched directly by the MEYS, this largely depends on the success of Czech participants in the co-funded calls of the QuantERA programme. The average amount per year would be <€1 million. As the budget of the MEYS, including the budget allocation dedicated specifically to R&D&I, depends largely on political negotiations and is constructed on a yearly basis – plus also, given the unpredictable situation concerning the COVID-19 pandemic and the need to mitigate its impact – it is not possible to give any estimation of the budget for the coming years.

Quantum Technology Programmes

The MEYS works as a National Funding Authority in the QuantERA programme and is an institution responsible for international cooperation in R&D&I in the Czech Republic. As such, it does not have any national funding programmes dedicated solely to Quantum Technologies. Furthermore, it provides institutional support to public universities and public research institutions; however, those are independent in the field of research performed. Therefore, research into Quantum Technologies may or may not be included in their activities. The MEYS is planning to continue its involvement in the QuantERA community once the proposal for QuantERA II is approved by the European

Commission and would continue to function as a National Funding Authority. An estimation of the budget for the potential first call of the QuantERA II programme is €500 k at the moment. The budget allocation on a potential second call of the QuantERA II programme has not so far been discussed.

Quantum Technology funding at national level

The Technology Agency of the Czech Republic is planning to be involved in the QuantERA II Programme should it receive the support of the European Commission. Besides that, research in Quantum Technologies can be funded through calls of various national funding providers, but there is no research call specifically dedicated to the area of Quantum Technologies. Usually, the calls are broad, do not focus on specific scientific domains and the topic is chosen by the applicant. For instance, the Czech Science Foundation supported several projects in Quantum Technologies in a call whose general scope was dedicated to fundamental research. Overall, research in Quantum Technologies has been supported by approximately €3,5 million per year in 2018 and 2019 respectively, given the sum of support of different providers and funding sources.

National Quantum Technology research community

The community of researchers in Quantum Technologies in the Czech Republic is well organised and consists of representatives of leading Czech universities and research institutions of the Czech Academy of Sciences. These are organised within the National Initiative for Quantum Technologies (NIKT), whose aim is to promote and support the development and usage of Quantum Technologies. The NIKT supported accession of the Czech Republic to the QuantERA programme, the Quantum Flagship and the EuroQCI. It can be said that the national research community, even though it is not large, is very active and is able to successfully articulate its interests and positions and serves as a good example of the bottom-up approach. It can also perform an advisory role for decision-makers and public officers in appropriate cases. In 2017, the NIKT also published a Roadmap of Quantum Technologies in Czechia that identifies streams of work of various research groups active in the Czech Republic in Quantum Technologies, their expertise and added value and can be used as a guiding tool for a synoptic overview of the Czech Quantum Technologies landscape.

Contact information

QuantERA

Michal Vávra
Michal.Vavra@msmt.cz

Quantum Community Network

Miloslav Dušek
Dusek@optics.upol.cz

Josef Lazar
Joe@isibrno.cz

DENMARK

Innovationsfonden:
Danish national funding agency, Innovation Fund Denmark (IFD)

Funding instruments

The Danish national funding agency, Innovation Fund Denmark (IFD), is funding quantum research and innovation through national open calls/programmes as well as in international co-funded programmes. The national calls are open to all scientific domains, with no restrictions on theme except on the organizational level. These calls are open to for-profit as well as non-profit research organizations and collaborative projects. The national calls are mainly organised under the Grand Solutions programme, which is aimed at collaborative projects based on excellent research focused on solutions of considerable value targeting societal and/or business challenges, opportunities and innovation needs.

Quantum research is sometimes specifically listed as one of the focus areas, but separate resources are not pre-allocated to the topic. International co-funded calls are mainly organised under Eurostars or EUREKA. Both platforms focus on applied research in collaborative projects with excellent research and a considerable scope for societal and commercial value. In addition to the Grand Solutions open call, funding is available for industrial PhDs and industrial postdocs with no restrictions on theme, which thus also includes Quantum Technology. So far there has been no relevant programme evaluation, portfolio analysis and/or foresight exercises performed in IFD with respect to Quantum Technologies.

Research priority areas in Quantum Technology

The national calls of IFD are open to all scientific domains, with no priority areas defined within QT. At the moment there is no national strategic research agenda for Quantum Technologies, but it is likely to come.

Quantum Technology funding within organization

IFD granted app. €3,5 million to 2 projects in 2020 and app. €4 million to 6 projects in 2019.

Quantum Technology Programmes

In 2019 IFD initiated an international call on AI & QT in EUREKA and IFD has dedicated funding to the QuantERA call 2019. The launch of new programmes in Quantum Technology research is being discussed, but there are no concrete plans yet.

Quantum Technology funding at national level

There are no other public bodies in Denmark supporting projects specifically related to Quantum Technologies.

National Quantum Technology research community

Historically, Denmark has a long tradition in the field of Quantum Technology, dating back to Niels Bohr himself, who started the Niels Bohr Institute at the University of Copenhagen. Here and at the Technical University of Denmark (DTU), several internationally renowned research groups are located, working on most aspects of Quantum Technology and its application to real world problems.

Lately these strong research groups (including other universities such as Aarhus University and Aalborg University) as well as our national RTO have succeeded in attracting public as well as commercial funding. In particular, at DTU and Copenhagen University, global ICT companies have invested heavily in platforms for cooperation with the Danish research community.

A number of startups specializing in quantum computing have materialised over the last 2-5 years, and banks and large biotech companies are participating in Grand Solutions projects on quantum computing.

Contact information

QuantERA

Børge Lindberg
Boerge.Lindberg@innofond.dk

Quantum Community Network

Jens Peter Vittrup
Jens.Peter.vittrup@innofond.dk

Eugene Polzik
Polzik@nbi.ku.dk

FINLAND

Suomen Akatemia: Academy of Finland (AKA)

Funding instruments

The Academy of Finland is funding Quantum Technologies (QT) research mainly through its national bottom-up calls for funding. There are funding forms for research projects, individual researchers and organisations via which funding for Quantum Technologies research can be applied for. Individual grants are available for postdoc and senior researchers. A certain amount of funding on a yearly basis is reserved for research projects by early-career principle investigators.

Research priority areas in Quantum Technology

The national calls are open to all scientific domains, with no priority areas defined.

Quantum Technology funding within organisation

Since there is no specific QT programme, an estimate of the financial support for QT projects is difficult to obtain. Nevertheless, based on a brief analysis of the Academy's September 2019 call, the funding granted for QT-related projects in 2020 can be estimated to be around €10 million.

Quantum Technology funding at national level

In Finland, QT research can be also supported by Business Finland, the Finnish government organisation for innovation funding and trade, travel and investment promotion. This agency's main focus is on funding industrial partners. There are also several national foundations that may fund QT-related projects.

National Quantum Technology research community

In Finland, there is a worldwide recognized community of researchers devoted to both theoretical and experimental work. Several members of the community are involved in the Quantum Flagship Initiative. There is also an Academy-funded Centre of Excellence in Quantum Technology[22] operating in Finland.

Contact information

QuantERA

Jukka Tanskanen
Jukka.Tanskanen@aka.fi

Quantum Community Network

Mikko Merimaa
Mikko.Merimaa@vtt.fi

22. https://www.aka.fi/en/research-and-science-policy/centres-of-excellence/centres-of-exellence-20182025/quantum-technology/

FRANCE

Agence Nationale de la Recherche: The French National Research Agency (ANR)

Funding instruments

The French national funding agency ANR funds quantum research through national calls. Each year ANR launches a national call with more than 45 evaluation panels working simultaneously. Each panel evaluates the proposals submitted within its topic. Each topic is described in the call with a short paragraph and keywords. One of these topics is Quantum Technologies. In this call, four types of research projects are evaluated and funded:

- Young researcher projects: only one partner can be funded, affiliated to a public research organisation. The goal is to support the development of a new research line carried by a young researcher who obtained his/her PhD no more than 10 years ago;
- Collaborative projects: several partners are funded affiliated to public research organisations. The goal is to support collaborative research efforts;
- Public/private collaborative projects: several partners are funded, with at least one affiliated to a private entity, while the others are affiliated to public research organisations, as the goal is to foster collaboration between public research and industry;
- Bilateral collaborations: every year the ANR cooperates with foreign research funding organisations to support bilateral collaboration between French research and researchers of other countries in the form of bilateral research projects. In a selected project, a minimum of one partner is funded by the ANR, while the partner(s) of other countries are funded by their respective funding organisations.

Before the addition to the national call of the Quantum Technologies evaluation panel in 2018, QT projects could obtain financial support from other evaluation panels, whose scientific topics were close to QT (e.g., Condensed and Diluted Matter Physics, etc.).

Research priority areas in Quantum Technology

A few priorities are defined and mentioned every year in the current national call for proposals. One of these priorities is Quantum Technologies, which manifests in the form of a strategic reserve of the State that can be used to fund additional projects in the Quantum Technologies evaluation panel, or other panels where some projects may have a significant Quantum Technologies component (e.g., the evaluation panel on Condensed and Diluted Matter Physics). The ANR national call for proposals[23] contains the description of the Quantum Technologies evaluation panel, and other evaluation panels have a clear mention if these can be supported by the strategic reserve of the State in Quantum Technologies.

At the ANR the Quantum Technologies national funding programme is associated with the ERC codes PE02, PE03 and PE06, and to the Sustainable Development Goals 9 (Industry, Innovation and Infrastructure) and 16 (Peace, Justice and Strong Institutions)

23. https://anr.fr/fileadmin/aap/2019/aapg-anr-2019-en-2.pdf

Quantum Technology funding within organisation

In the 2019 national call, the value of projects selected for funding in Quantum Technologies corresponded to €5.3 million. This does not take into account the part of the strategic reserve of the State on Quantum Technologies that was used to fund a few proposals submitted to other evaluation panels of the national call, but which had a Quantum Technologies research component as well. Additionally, a national initiative started in 2010 called "Major Investments for the Future", has a part of its funding used at the ANR to support Quantum Technologies research projects through a specific call for proposals (separate from the yearly national call for proposals).

Quantum Technology funding at national level

"Major Investments for the Future", the national initiative mentioned above, has the rest of its funding used by BPI-France, a public investment bank that funds and invests in private entities through various schemes (some of which can include the participation of public research partners). QT is an area supported by BPI-France.

Private entities can also use a scheme called Credit Import Recherche, where their taxes are reduced if they perform research and development activities.

Some regions in France have regional research funding programmes where QT projects could potentially apply and be funded. For instance, the region Île-de-France has a funding programme called DIM (Domaines d'intérêt majeur), with a 2017-2020 project SIRTEQ, a network of researchers in QT.

Contact information

QuantERA

Sergueï Fedortchenko
Serguei.Fedortchenko@agencerecherche.fr

Quantum Community Network

Philippe Grangier
Philippe.Grangier@institutoptique.fr

Sebastien Tanzilli
Sebastien.Tanzilli@unice.fr

GERMANY

Bundesministerium für Bildung und Forschung: Federal Ministry of Education and Research (BMBF)

Funding instruments

The BMBF research funding in Quantum Technologies is programme-based and organised mainly through thematic calls. Recent calls include topics such as 'Quantum processors and technologies for quantum computers' or 'Applied research in quantum sensor technology, metrology and imaging'.

The thematic calls are complemented by open calls for certain aspects such as SME and startup support as well as scientific preparatory/early stage projects. Unless certain target groups are addressed (e.g. SME), the calls are generally open to universities, research organisations and enterprises.

In addition, there are specific subprogrammes and supporting measures aimed at the promotion of young talents (*'Quantum Futur' Competition*) and students (*'Quantum Futur' Academy*).

Research priority areas in Quantum Technology

There are three vertical and one horizontal research priority areas:

- Quantum computer (and simulation)
- Quantum communication (and cryptography)
- Quantum based measurement (and sensing) technology
- Basic technologies for quantum systems

The national governmental strategy focuses on measures in the following fields of action:

- Expanding the research landscape for Quantum Technologies
- Creating research networks for new applications
- Establishing lighthouse projects for industrial competitiveness
- Ensuring security and technological sovereignty
- Shaping international cooperation
- Involving the citizens and the general public

Quantum Technology funding within organisation

The budget for the funding of Quantum Technologies administered by BMBF and VDI TZ is currently in the range of €20 to 30 million per year. A significant increase is planned for the coming years.

Quantum Technology Programmes

In 2018 the German Federal Government launched the multi-annual framework programme 'Quantentechnologien – von den Grundlagen zum Markt' ('Quantum technologies – from basic research to market')[24] which is implemented through the auspices of the BMBF (Federal Ministry of Education and Research) operationally supported by its responsible project funding agency VDI TZ.

The Federal Government announced the provision of funds of approximately €650 million between 2018 and 2022 (duration of the programme). However, a large share of this amount is dedicated to basic funding of research organisations and to infrastructural and accompanying measures. This includes scientific funds administered by other funding bodies (e. g. the DFG) and by larger research associations (e. g. Helmholtz Association and Max Planck Society). Thus, only a smaller part of the budget will be available for individual project funding measures. It is planned to continue the programme until 2028.

24. https://www.quantentechnologien.de/fileadmin/public/Redaktion/Dokumente/PDF/Publikationen/Federal-Government-Framework-Programme-Quantum-technologies-2018-bf-C1.pdf

Quantum Technology funding at national level

In addition to the national approach described above, also some federal states like Baden-Wuerttemberg and Bavaria also fund Quantum Technology, mainly through the establishment of dedicated institutes and competence centres.

National Quantum Technology research community

Germany has an excellent starting position in basic research in quantum physics. In many different places throughout the country, research into Quantum Technologies is being carried out at international level. Despite a partial lack of coordination in some areas, the broad research in this field – consisting of a federally structured university landscape, non-university research institutions, departmental research and market-oriented research of companies – forms a promising basis for a sustainably efficient research and innovation landscape in Quantum Technologies.

Contact information

QuantERA

Sebastian Krug
Krug@vdi.de

Quantum Community Network

Tommaso Calarco
T.Calarco@fz-juelich.de

Thomas Strohm
Thomas.Strohm@de.bosch.com

GREECE

Γενική Γραμματεία Έρευνας και Τεχνολογίας:
General Secretariat for Research and Technology (GSRT)

GSRT
GENERAL SECRETARIAT FOR RESEARCH AND TECHNOLOGY

Funding instruments

GSRT is the main body responsible for setting and coordinating the implementation of research, technology development and innovation policy and is the major direct funder of R&D.

Quantum Technologies research is funded through regional open calls/programmes in the context of the Operational Programme for Competitiveness, Entrepreneurship and Innovation 2014-2020 (EPAnEK), National Research and Innovation Strategy for Smart Specialization 2014-2020. The calls are open to all scientific domains, with no restrictions on theme.

Research priority areas in Quantum Technology

Within Quantum Technologies, GSRT has defined quantum optics, quantum computation and simulation, and quantum material as national priority areas.

Additionally, there is no national or regional research agenda for Quantum Technologies, defining priority areas in QT.

Quantum Technology Programmes

The total committed budget for Greece was €2 million for the thematic bilateral call on joint R&D projects on Quantum Technologies between Greece and Russia. Within the current operational programme, SMEs are encouraged to participate in proposals to be funded. There is no specific information available on the funding into Quantum Technologies within GSRT. It is not known whether the funding for Quantum Technologies will be increased in the coming years.

National Quantum Technology research community

No other funding bodies are known to be funding Quantum Technologies at national level at the moment.

Contact information

QuantERA

Anna Rosenberg
A.Rosenberg@gsrt.gr

Quantum Community Network

Dimitris Angelakis
Dimitris.Angelakis@gmail.com

HUNGARY

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal : National Research, Development and Innovation Office (NKFIH)

Funding instruments

The National Research, Development and Innovation Office is a national strategic and funding agency for scientific research, development and innovation. In accordance with its annual programme strategy, it funds both strategic programmes in targeted areas, such as Quantum Technologies, as well as bottom-up programmes.

HunQuTech – National Quantum Technologies programme

As part of its programme strategy, the National Research, Development and Innovation Office is funding the National Quantum Technologies Programme[25], a four-year programme (2017-2021) offering €11 million funding for Quantum Technologies research and development. The programme is funded within the National Excellence Programme[26]. The programme brings together outstanding research groups in Hungary, as well as a number of industrial partners. The strategic research agenda is defined by the consortium implementing the programme and is aligned with the European Quantum Technologies Flagship.

Bottom-up programmes

Some of the bottom-up programmes, where it is possible to apply for funding for projects that address Quantum Technologies, for example, are researcher-initiated thematic applications, support for research teams with internationally prominent achievements. Some of the funding schemes include:

- Call for researcher-initiated thematic applications is open for discovery research projects of Hungarian research centres in any field of science without thematic priorities (Most recent call: K_19)
- "Frontline" – Research Excellence Programme provides targeted funding to world-class researchers with internationally prominent achievements (Most recent calls: KKP_19, KKP_17)
- Calls for research teams with significant achievements of internationally outstanding impact (Most recent call: KH_18)
- Calls for businesses and/or academy/industry collaboration, such as support of business RDI activities, support for market-driven RDI, and competitiveness and excellence cooperations
- Researcher initiated projects based on international cooperation, calls for cooperations with specific countries and calls based on bilateral R&D cooperation agreements
- Calls targeting young researchers (see section below)

International programmes

Hungary participates in the Horizon 2020 ERA-NET Cofund Quant-ERA, where funding is dedicated to projects linked to the European Quantum Technologies flagship. Several projects including Hungarian participants have been funded.

Young scientists

Programmes for young scientists are open programmes, where scientists addressing Quantum Technologies can apply.

1. Run by the National Research, Development and Innovation Office, two of the programmes are dedicated to young researchers (FK, PD)s, while one receives numerous applications from young researchers (K)s:
   - Call for researcher-initiated thematic projects (Most recent call: K_19)

25. https://wigner.mta.hu/quantumtechnology/en
26. http://nkfih.gov.hu/funding/calls-of-the-national/national-excellence

- Call for young researchers to establish their independent research groups (Most recent call: FK_19)
- Call for postdoctoral applications (Most recent call: PD_19)

2. Run by the *Hungarian Academy of Sciences*
   - Lendület ("Momentum") Programme[27]

Furthermore, non-research funding options are similarly of an open nature; not specifically dedicated to certain technologies. Quantum Technologies are featured in doctoral schools and university courses, as well as summer schools.

Research priority areas in Quantum Technology

Quantum Technologies – as such – are defined as a priority area. The national programme addresses all the pillars that are highlighted in the European Quantum Technologies Flagship.

Quantum Technology funding within organisation

The HunQuTech programme is the main instrument of funding for Quantum Technology research in Hungary. Its budget is €11 million for 5 years. A follow-up programme is planned.

In addition, Quantum Technology-oriented projects can be funded through other open calls under the national programme strategy[28].

Hungary also contributes national funding to transnational projects that have succeeded through the QuantERA calls, and an increased budget is planned for future calls.

Other Quantum Technology funding at national level

The Hungarian Academy of Sciences has funded the "Lendület" Momentum programme since 2009 to support young scientists, who consistently achieve exceptional, internationally-recognised research results. Researchers working in Hungary, as well as those working abroad but willing to return to set up a research group, are eligible to apply and secure funding for five years. The calls under the Momentum programme are bottom-up, without a thematic focus.

As a result of these calls, several young scientist-led research groups working on Quantum Technologies are receiving support currently and have been supported through past calls.

National Quantum Technology research community

In Hungary, research into Quantum Technologies – including fundamental science and applied research – involves a number of internationally-recognised academic institutions, as well as industrial actors. The field is attracting an ever-growing interest among young researchers as well.

The HunQuTech programme has had a structuring effect on the Hungarian Quantum Technology community by bringing together a critical mass of outstanding Hungarian research groups and industrial partners. They also include several research groups that are winners of the prestigious Momentum programme of the Hungarian Academy of Sciences and ERC starting grants.

HunQuTech includes: Wigner Research Centre for Physics, Institute of Physics, Budapest University of Technology and Economics, Faculty of Electrical Engineering and Informatics, Budapest University of Technology and Economics, Institute of Physics of the Eötvös Loránd University, Bonn Hungary Electronics, Ericsson Hungary, Nokia-Bell Labs and Femtonics.

27. https://mta.hu/english/mta-lendulet-momentum-programme-20202025-110368

28. https://nkfih.gov.hu/english-2017/calls-to-foster-rdi/system-of-domestic-rdi

Contact information

QuantERA

Edina Nemeth
Edina.Nemeth@ist.hu

Quantum Community Network

Peter Domokos
Domokos.Peter@wigner.mta.hu

Ádám Gali
Gali.Adam@wigner.mta.hu, AGali@eik.bme.hu

IRELAND

Science Foundation Ireland (SFI)

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

Funding instruments

Science Foundation Ireland (SFI) funds Quantum Technologies research through many of its open calls and programmes that are open to all scientific domains. These include individual awards (Career Development Awards, Investigator Programmes). Some of them target early career (Starting Investigator Research Grant) and more senior researchers (Research Professorships)

Quantum Technology projects funded by SFI in the last five years mostly fall under the National Research Priority Areas of Future Networks, Communications and Internet of Things, Manufacturing and Novel Materials, and Digital Platforms Content and Application. Quantum Technology projects have also been supported by SFI in terms of infrastructure grants and Conference and Workshops funding.

However, SFI does not currently run thematic programmes in Quantum Technologies.

Research priority areas in Quantum Technology

Over the last five years SFI has funded numerous Quantum Technology-based projects. Of these, over 70% were focused on Quantum Information Sciences and Quantum Metrology, Sensing and Imaging. Other subject areas covered in the remaining 30% include Quantum Computation, Quantum Simulation and Quantum Communication. SFI does not have a national strategic research agenda for Quantum Technologies.

Quantum Technology funding within organisation

Although SFI has no specific Quantum Technologies programme, an estimated 25 Quantum Technology-themed projects have been funded by SFI over the last five years through an investment of approximately €24 million, i.e. approx. €5 million *per annum.*

Quantum Technology Programmes

There is no dedicated funding programme for Quantum Technologies within SFI. No upcoming programme is expected in the next three years.

Quantum Technology funding at national level

No other public research funding bodies are supporting QT projects in Ireland. There is a growing number of R&D activities in the private sector, including multi-national corporations such as IBM, Intel and Google as well as several recently emerging SMEs.

National Quantum Technology research community

Ireland has a well-established, strong and rapidly growing research community in Quantum Technologies both in academia and the private sector. There is over thirty Principal Investigators directly involved in Quantum Technologies in Irish universities and a growing number of R&D activities in the private sector, including multi-national corporations such as IBM, Intel and Google as well as several recently emerging SMEs.

Ireland has a particular strength in quantum computing. Maynooth University, which currently leads the Quantum Community Network in Ireland, has over twenty years of tradition in theoretical research in both conventional and topological quantum computing. Tyndall National Institute and University College Dublin focus primarily on experimental quantum computing implementation in photonic and solid-state systems, respectively, and the Irish Centre for High-End Computing concentrates on algorithms and simulations in the context of high-performance computing. Quantum research relevant to quantum technologies, including both theory and experiments, is also pursued at Dublin Institute for Advanced Studies, Trinity College Dublin, University College Cork and NUI Galway. Strong interests in quantum technologies exist also at Dublin City University and University of Limerick.

Contact information

QuantERA

Maria Nash
Maria.Nash@sfi.ie

Quantum Community Network

Jiri Vala
Jiri.Vala@mu.ie

ISRAEL

לשכת המדען הראשי :
Council for Higher Education / The Israel Innovation Authority (ISERD)

רשות החדשנות
Israel Innovation
Authority

Funding instruments

The Israel National Quantum Initiative (INQI) is a joint venture of the leading R&D funding agencies in Israel. These include the Council for Higher Education, the Israel Innovation Authority (under which ISERD is the agency in charge of R&D relations within the EC framework – the MFF), the Ministry of Science, the Ministry of Defense and the Ministry of Finance. These agencies all cooperate in INQI, which is headed by a small executive body in charge of coordination.

INQI was formed in 2019. Some components have already been budgeted and are operating. Some will be initiated in the next few months pending final approval in the general State Budget by the government. The overall budget framework of the programme is approximately €325 million (1.25B NIS) over about 5 years.

For each component in the Initiative, one of the agencies is defined as the leading partner, and the activities of that component are operated through one of the budgeting and management platforms in that agency. For example, a direct academic research fund is operated through the Council for Higher Education, while an industrial quantum sensing consortium is operated through the Israel Innovation Authority.

The principles of INQI include maintaining a high level of excellence in all activities, hence all components are realised in competitive, open, processes, and expert reviews are made before the relevant committees decide on the winning proposals. Some of the components are restricted to academic- or industrial-only participation, but some are not restricted. Some are also open for non-Israeli entities to be involved.

Quantum Technology funding at national level

INQI consists of several lateral components, which have no preference to any sub-field of quantum science and technology, and 2 main focus areas.

Two main focus areas in the INQI, and a minor one:

- Main focus area – **quantum sensing** – pushing mainly existing industries in this field, to mature the technology and assist in enhancing competitive edge in the market. An industry consortium was formed in a competitive process, and other projects in various programmes, some top-down, some bottom-up.
- Main focus area – **quantum computing and simulation** – with the aim of significantly enlarging the Israeli community in this sub-field. This contains several sub-components, including a dedicated call-for-proposals for working on state of the art quantum computing platforms in the cloud, investments in academia to generate large groups of training for experts in the field, and investments in applied quantum computing infrastructure as a national project. In addition, we intend to invest and encourage new startup companies to form around this infrastructure to enhance the eco-system.
- Minor focus area – **QKD** – a main project for a system level testbed for QKD. Now being enhanced and integrated with an industrial consortium.

The lateral components include:

- A **direct academic research fund** – the goal is to enlarge and support excellent academic research, typically in a consortia of several researchers working together.

- Human capital – this is the main tool for enlarging the Israeli QST community. This component consists of many different activities, including for example:
  - Funds to assist in recruitment of new academic faculty in QST, including formation of personal labs, scholarships for students, and more;
  - Funds oriented to improve and adjust education programmes, and to enhance the multidisciplinary nature of the field;
  - Programmes for excellent PhD students;
  - Programmes to support Israeli graduates going for post-doc fellowships abroad;
  - Programmes to enhance the academa-industry interface (in both directions).
- **Substantial infrastructure** (mostly in academia) to support excellent quantum research. This includes large grants to form infrastructure facilities dedicated to QST fabrication, characterisation, or other equipment, meant for common use (and not for personal labs). This includes interface between academia and industry, as well as the relevant expert technical manpower required to operate the equipment and infrastructure
- **International collaboration** – incentives to be added to existing international collaboration platforms such as binational funds to push QST with foreign partners.
- **Critical components for the quantum industry** – funds dedicated to support Israeli QST industry with regards to development of capabilities related to critical components (e.g. specialised laser sources).

Although the main partners are the R&D agencies mentioned above, we always strive to enlarge the Initiative, with additional partnerships within the Israeli government, venture capital firms, multinational corporations and more.

Quantum Technology Programmes

- The **direct academic research fund –** €30 million for 5 years. Round A of the programme already launched with a budget of about €18 million. Currently there are 10 main projects running and some small projects as well. In 2021 the INQI will launch round B of the programme;
- **Knowledge transfer initiative in quantum sensing** – €16 million for 3 years;
- The **QKD programme** – €2.5 million. The programme is about to raise the budget for further development in 2021 and to create a new Academic and Industry consortia in this area;
- INQI had launched a new call for **Substantial infrastructure** (mostly in academia) to support excellent quantum research. This includes large grants to form infrastructure facilities dedicated to QST fabrication, characterisation or other equipment, meant for common use;
- Participation in **QuantERA** – about €1 million per QuantERA call;
- IIA calls and Eureka calls – the budget will be decided based on projects excellence.

National Quantum Technology research community

Israel's QST academic research community is composed of ~110 research groups in 8 academic research centres. In fact, this number has been growing rapidly since 2020, as we see researchers from adjacent fields such as photonics and optics move their interests into QST. Almost all the Israeli universities have formed QST centres, arranging and coordinating activities and developing infrastructure at the university level. These QST centres bring together researchers not only from physics, but also from applied physics, engineering, computer science, and in some cases other disciplines.

Israel's QST industry is seeing rapid development in the past 2 years, growing from about 3 companies to over 20. These includes large companies as well as startups and Quantum component companies.

INQI is now in advanced initiation stages. We hope to have a website up and running soon.

The private sector

In 2020 – two new private accelerators were initiated – focus on Quantum Technology and other data centric initiatives: the Intel Accelerator[29] and the Quantum Hub[30].

Contact information

QuantERA

Dan Seker
Dan@iserd.org.il

Quantum Community Network

Nadav Katzn
Katzn@racah.phys.huji.ac.il

29. https://newsroom.intel.com/news-releases/intel-announces-program-israeli-startups-targeting-tech-inflections/#gs.9imvzx

30. https://www.linkedin.com/company/quantum-hub/?originalSubdomain=il

ITALY

Ministero dell'Università e della Ricerca / Consiglio Nazionale delle Ricerche: Ministry of Universities and Research / National Research Council of Italy (MUR/CNR)

Funding instruments

In Italy there is a plurality of funding agencies under different ministries. In particular, the Ministry for University and Research (MUR) funds research in Quantum Technologies using different RFOs. MUR and the National Research Council of Italy (CNR) are both funding Quantum research through national calls. The national calls are open to all scientific domains, with possible restrictions on theme or participating entities depending on the specific call. For example, CNR calls are addressed to CNR researchers and associated researchers whereas MUR calls are open to all researchers in Italy, including industrial partners.

There are three main types of research projects:

- Young Talents Projects: Individual projects specific to MUR for researchers in the early stage of their careers;
- Excellence science projects: Collaborative research, to generate new general scientific knowledge;
- Challenge research projects: Collaborative research, to support research applied/oriented to solve societal and industrial challenges. In the case of MUR, calls can include Industrial Partners.

In addition to these research project calls there are other relevant calls to mention:

- European funded projects. The goal is to support the international projects like those in QuantERA or take part in Coordination support actions, such as the QFLAG project, and to the QT Flagship initiative such as the QOMBS project coordinated by CNR itself;
- Ministry of Economic Development (MISE): Industry oriented calls taking into account quantum applications through the collaboration between research entities and Public Administrations. Include the use of EU-matching funds.
- Ministry of Defence: Industry oriented calls taking into account quantum applications through the collaboration between research entities and Public Administrations.

Both MUR (through Universities) and CNR are funding specific Doctoral Schools related to Quantum Technologies. As mentioned, MUR has a specific programme dedicated to Young Talents (Scientific Independence of young Researchers SIR) although covering all scientific fields and not specifically dedicated to Quantum Technologies.

There is an ongoing programme evaluation with respect to Quantum Technologies. MUR is producing the National Research Plan which includes Quantum Technologies as one of its prominent fields. The plan analyses current national research and development activities in the field and calls for actions and dedicated infrastructures to be realised until 2027.

CNR is currently launching a Quantum Simulation Hub dedicated to the realisation of quantum co-processors with the aim of opening the facility to external users, including private companies.

Research priority areas in Quantum Technology

Approved projects in the past 5 years have covered all areas within Quantum Technology. The National Research Plan indicates 6 areas of priority in Quantum Technologies: Quantum computing and simulation, Quantum communication, Quantum sensing and metrology, Quantum Technologies for energy and environment, Quantum infrastructures, and education/training in Quantum Technologies.

Quantum Technology funding within organisation

Estimated funding into Quantum Technologies has been €2 million per year over the past 5 years. Next year's financial commitments have yet to be approved. Research plans foresee an increase of above a factor of ten over the previous 5 years.

Quantum Technology Programmes

There is not a specific QT Funding programme but for the involvement in the QuantERA project and the QT Flagship. Research Infrastructures in Quantum communication, Quantum simulation and Quantum Metrology are being built. The new national research plan foresees new programmes of investment but financial instruments have yet to be approved.

The national plan will include actions on:

- Support for Higher Education Programmes in interdisciplinary and inter-sectorial Doctoral studies in Quantum Technologies;
- Alignment of the national competitive calls for fundamental and applied research reserving a quota for Quantum Technologies;
- Co-financing and promotion, jointly with other ministries and/or with Italian Regions, to facilitate common investment with private companies, spin-offs and startups active in Quantum Technologies to foster the transformation of skills and results deriving from research activities into product prototypes, patents or technological solutions.

Quantum Technology funding at national level

Currently there are existing plans for Quantum Technology funding from different Ministries (see above). Different Regions of Italy are placing Quantum Technologies on their Strategic Research Agenda. The private sector is yet to be organised but different initiatives are appearing from Investment Funds across the country.

National Quantum Technology research community

Italy has played an important role in European Quantum Technology projects, in a constant way, since the 5th Framework Programme (i.e. for about 20 years). This has allowed the growth of one of the largest communities in Europe, including more than 60 groups and with some of the most authoritative research centres and scientists in the sector, 32 of which are winners of funding from the ERC. Italy was also the first European nation to implement a national network for communications and quantum metrology, the infrastructure called "Quantum Backbone". Furthermore, Italy is strengthening its leading role on the European scene by intervening directly, thanks to MUR and with the coordination of the CNR and the participation of INRIM and INFN, in the QuantERA ERA-NET Cofund with major investments aimed at fundamental research, the essential engine of technological innovation in the sector. Italy, in the initial phase of the Flagship on Quantum Technologies, has already obtained total financing of approximately €14 million, against a national co-financing of €3 million, having obtained, with highly competitive procedures, the approval of 26 Projects, 6 of which with Italian coordination.

Active infrastructures for Quantum Technologies in Italy are:

- Italian Quantum Backbone (IQB): developed from 2013 to 2019 by the Istituto Nazionale di Ricerca Metrologica (INRIM) and CNR. A research infrastructure based on a fibre-optic backbone, devoted first to the dissemination of atomic clock signals, and then to quantum communication and Quantum Technologies. IQB today relies on 1850 km long fibre haul, connecting the main Italian cities: Turin, Milan, Bologna, Florence, Rome, Naples, Salerno, Matera. The IQB links the French-Italy border in the Frejus tunnel on the Alps, and can be extended towards Europe through Milan (to Switzerland) and to Austria and Germany through Verona and Brennero.
- Piattaforma italiana per lo sviluppo di coprocessori quantistici (PAS(C)QUA): Infrastructure for the development of quantum coprocessors based on atoms and photons. A new generation of quantum simulators designed to be interfaced with classical supercomputers. Future access for companies interested in the new technology is foreseen. Realized by CNR with the co-financing by MUR.

Contact information

QuantERA

Francesco S. Cataliotti
fsc@lens.unifi.it

Chiara Mustarelli
info.quantera@cnr.it

Giorgio Carpino
Giorgio.Carpino@miur.it

Aldo Covello
Aldo.Covello@miur.it

Quantum Community Network

Paolo de Natale
Paolo.deNatale@ino.cnr.it

Chiara Macchiavello
Chiara.Macchiavello@unipv.it

LITHUANIA

Lietuvos mokslo taryba : Research Council of Lithuania (LMT)

Funding instruments

The Research Council of Lithuania allocates funds to state-commissioned and researcher-initiated research, the projects of international co-operation programmes and activities promoting the careers and mobility of researchers. The relevant national research programme in Quantum Technologies is “Towards the future technologies”. Even if this programme is not exclusively dedicated to quantum research, however, quantum research is within the scope of the programme.

The Council also allocates funds to bottom-up researcher-initiated research and international cooperation projects, with some of them targeted toward quantum research.

The Council does not operate any specific funding programmes to promote young scientists that include Quantum Technology topics

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Research priority areas in Quantum Technology

There are no specific priority areas related to Quantum Technologies.

Quantum Technology funding within organisation

There is no specific information available on the funding into Quantum Technologies within LMT. It is not known if funding for Quantum Technology will be increased in the coming years.

Quantum Technology Programmes

Recently there are no initiatives to launch new separate programmes to fund Quantum Technology research.

Contact information

QuantERA

Saulius Marcinkonis
Saulius.Marcinkonis@lmt.lt

Quantum Community Network

Audrius Alkauskas
Audrius.Alkauskas@ftmc.lt

LATVIA

Valsts izglītības attīstības aģentūrā : State Education Development Agency (VIAA)

Funding instruments

The Latvian national agency, VIAA (State Education Development Agency) implements national policy in the fields of development of higher education and science, lifelong learning systems, as well as in general and vocational education systems. Funding of research projects is not the core activity of VIAA, but rather activities associated with participation in ERA-NET projects including QuantERA. Accordingly, in VIAA there are no specific national programmes for funding projects in Quantum Technologies. There are other funding organisations that can fund research projects including Quantum Technology projects.

VIAA has specific funding programmes to promote young scientists. It promotes young scientists within the framework of "Post-doctoral Research Aid". The themes may include Quantum Technology topics.[31]

Research priority areas in Quantum Technology

There are no specific priority areas in Quantum Technologies. All projects are bottom-up initiatives with themes defined by researchers.

Quantum Technology funding within organisation

In VIAA there is no specific funding programme for Quantum Technologies. Specifically, projects in the Quantum Technology field are funded within the framework of QuantERA (and eventually QuantERA II). For each ERA-NET call VIAA allocates €300 k, but can adjust funds depending on the number of projects recommended for funding in each call.

Quantum Technology Programmes

In VIAA there are no dedicated funding programmes for Quantum Technology research nor plans to launch such programmes in the next three years.

Quantum Technology funding at national level

In Latvia, fundamental and applied research projects are funded by the Latvian Council of Science. The calls are announced once a year and are open for all topics including Quantum Technologies. The project proposals are evaluated by independent experts. The selected projects are funded by the Latvian Council of Science.[32]

There is also the possibility to get support for Quantum Technology research from the Central Finance and Contracting Agency (CFLA) which manages the Latvia European Regional Development Fund (ERDF), Cohesion, and other funds. For example, international collaboration in Quantum Technologies can be supported in the call "Support for transnational cooperation projects in research and innovation".[33]

31. http://viaa.gov.lv/lat/pecdoktoranturas_atbalsts/pecdoktorantura_apraksts/
32. https://www.lzp.gov.lv/index.php?mylang=latvian
33. https://cfla.gov.lv/lv/es-fondi-2014-2020/izsludinatas-atlases/1-1-1-5-k-3).

National Quantum Technology research community

Most of the Quantum Technology research in Latvia is concentrated in the University of Latvia or its research institutes:

- Research on quantum algorithms takes place in the Center for Quantum Computer Science at the Faculty of Computing.
- In the Laboratory of Computer Modelling of Electronic Structure of Solids of the Institute of Solid State Physics, large-scale first-principles computer simulations are performed.
- In the Institute of Atomic Physics and Spectroscopy, two laboratories perform research in quantum areas – Quantum Optics Laboratory and Laboratory of Theoretical Physics.
- In the Theoretical Physics Department of the Faculty of Physics, Mathematics and Optometry, one of the research directions is quantum mechanics.

When it comes to the practical applications, a Latvian company Eventech, Ltd. has developed an ultra-precision timer that can be used as a valuable tool for many quantum optical measurements.

Contact information

QuantERA

Juris Balodis
Juris.Balodis@viaa.gov.lv

Quantum Community Network

Andris Ambainis
Andris.Ambainis@lu.lv

Vjačeslavs Kaščejevs
Vjaceslavs.Kascejevs@lu.lv

NETHERLANDS

Nederlandse Organisatie voor Wetenschappelijk Onderzoek: The Dutch Research Council (NWO)

Funding instruments

The Dutch Research Council (NWO) provides a spectrum of funding instruments from which quantum research can be funded. Generally, these instruments are open to all scientific domains, with no specific focus areas. All calls are open to researchers affiliated to Dutch universities, research institutes and knowledge institutes; some of the instruments require a consortium with an external co-financing partner or partners.

Below the available NWO funding instruments are listed:

- Knowledge and Innovation Covenant (KIC) 2020-2023: this instrument provides funding for fundamental and practical research in a public-private partnership (PPP), and is open to all scientific domains. The set of instruments consists of four main lines, for which €118 million/yr has been reserved; co-funding is required for all lines. The four lines are: mission (€55 million), demand (€15 million), strategy (€30 million), practice (€18 million).
- Dutch Research Agenda – "NWA" (€130 million): this instrument is aimed at solving societal and economic challenges. The agenda consists of 25 routes, of which "The quantum/nano revolution" is one.
- Talent program (€150 million): this programme offers personal grants to talented, creative researchers, starting with postdocs (Veni), tenures (Vidi) and permanent staff (Vici). The funding enables applicants to do their own line of research, including Quantum Technology.
- Open Competition (€82.5 million): researchers can apply individually or in collaboration for curiosity-driven, fundamental research. Within this programme, there are small-scale (KLEIN, XS) and large-scale (GROOT) grants.
- Open Technology Program (€23 million): The programme offers companies and other organisations an easily accessible way of becoming involved in scientific research that leads to usable knowledge. Co-funding is required for projects exceeding €600k.
- Perspective (€22 million): within this instrument, scientists work with a consortium of companies on specific scientific topics in order to further develop a technology.
- Take-off (€3.8 million) and Demonstrator (€1 million): with Take-off, NWO gives new entrepreneurs that last helping hand towards the market; with Demonstrator, it helps with the development of a demonstration model.

Research priority areas in Quantum Technology

Currently, the funding instruments are open to all scientific domains, with no specific focus areas.

Last year, researchers in the field of Quantum Technology presented the "National Agenda Quantum Technology (NAQT)". The focus areas in this agenda are defined into three "catalyst" (CAT) programmes and four action lines:

In response to the NAQT initiative, the Department of Economic Affairs & Climate has awarded €23.5 million for five years as a starter impulse in order to kick-start the proposed NAQT programme. The organisation and administration of this funding will be handled by an independent foundation "QuantumDeltaNL"[34]. NWO is part of the Supervisory Board.

34. www.quantumdelta.nl

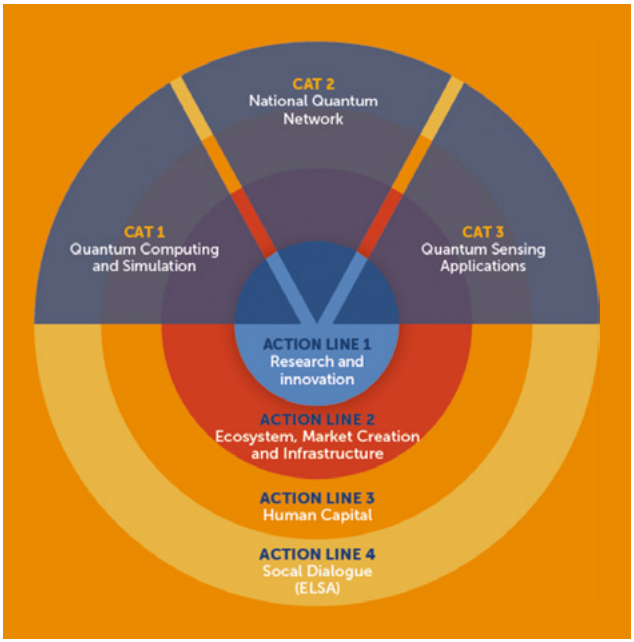

Figure: the NAQT programme is divided into CAT programme and action lines. CAT 1 is dedicated to "Quantum Computing and Simulation, CAT 2 to "National Quantum Network", and CAT 3 to "Quantum Sensing and Applications". The action lines are defined as "Research and Innovation"(AL-1), "Ecoystem, Market Creation and Infrastructure" (AL-2), "Human Capital" (AL-3), and "Social Dialogue" (AL-4).

Quantum Technology funding within organization

Quantum Technology-related research projects from all instruments collectively add up to €18 – 20 million/yr.

Quantum Technology Programmes

Currently, there are no thematic QT focus programmes in place.

For the coming year(s), there will be multiple opportunities. First, the mission line within the KIC 2020-2023 funding instrument will develop the structure for a call around the key enabling technologies, of which Quantum Technology is one. Depending on the preference of the field, this could then result in a thematic QT call, and will likely result in a relative increase of the dedicated QT funding.

Next, within the Dutch Research Agenda, there has recently been a thematic call awarded "Quantum Technology and Society" (€3 million). Here, the Department of Economic Affairs & Climate, the Department of Defense together with NWO will be organizing a call open to all Dutch researchers conducting Quantum Technology-related research. The call will open in 2021 – more information will follow.

Quantum Technology funding at national level

Next to NWO, there are no alternative public funding agencies available such as regional funds to apply for either fundamental or PPP research projects. However, as Quantum Technology is and for years has been a strong field of research in the Netherlands, the (co-)financial contribution of national and international private partners is significant: next to Dutch startups, big players such as Microsoft, Intel and ABN AMRO are currently closely collaborating with researchers on QT projects. Multiple other big parties have indicated their interest in future investments (e.g. discussions with IBM are on-going).

National quantum technology research community

The Netherlands has a strong background in the field of Quantum Technology and is globally recognised as one of the leaders in terms of the QT-related scientific research. Next to individual research groups at the Dutch universities and research institutes, there are currently five quantum expertise institutes, each with their own focus areas, ranging from topological qubits, quantum-photonic devices, to quantum simulation, post-quantum cryptography and quantum software. These institutes have attracted a lot of young (inter-)national talent over the years. There is efficient knowledge exchange between groups, which due to the geographically small distances within the Netherlands, facilitates close collaborations between Dutch research groups and has led to an acceleration of the development of certain QT-related technologies (e.g. quantum sensors, quantum simulators).

As mentioned above, since last year the national coalition QuantumDeltaNL has been initiated to write and eventually administrate the NAQT. Through a national Sounding Board, consisting of researchers, industry, banks, ministries and knowledge institutes, they keep close communication with the field to discuss preferences, wishes and expectations.

Last year NWO has installed an NWO Quantum Committee, consisting of QT researchers, covering the entire QT spectrum, which has a similar function for our organization as the Sounding Board for the QuantumDeltaNL coalition. In this way, we keep up to date on recent developments and opportunities within the field.

Contact information

QuantERA

Wieteke de Boer
W.deBoer@nwo.nl

Quantum Community Network

Giordano Scappucci
G.Scappucci@tudelft.nl

NORWAY

Forskningsradet: The Research Council of Norway (RCN)

Funding instruments

Quantum Technology research in RCN is funded through bottom up research calls for researcher projects and some top down funding through ICT related calls in security and software.

Research priority areas in Quantum Technology

There are no specific priority areas related to Quantum Technologies. There is no national or regional research agenda for Quantum Technologies, defining priority areas in QT technologies.

Quantum Technology funding within organisation

RCN has no specific funding programme for Quantum Technologies. The estimated funding for QT through regular calls is estimated at €2-5 million. No increase of budget is expected in the coming years.

Quantum Technology funding at national level

There is no information available any other national public or private research funding bodies supporting the research projects related to the areas of the QT.

National Quantum Technology research community

Prof. Kjetil Børkje (USN) and Prof. Susanne Viefers (UiO) are the Norwegian representatives in the QCN network. They are heading a national network of scientists working in QT-related areas.

Contact information

QuantERA

Pål Sigurd Malm
psma@forskningsradet.no

Quantum Community Network

Prof. Kjetil Børkje
Kjetil.Borkje@usn.no

Prof. Susanne Viefers (UiO)
S.F.Viefers@fys.uio.no

POLAND

Narodowe Centrum Nauki: National Science Centre (NCN)

NATIONAL SCIENCE CENTRE POLAND

Funding instruments

The National Science Centre (NCN) is a Polish government agency funding Quantum research through a variety of national calls. NCN supports basic research conducted within the framework of scientific projects, doctoral scholarships and postdoctoral fellowships, as well as individual research activities designed to contribute to broader basic research. Calls for proposals are open to all researchers, irrespective of age and experience. The NCN call portfolio currently includes nine domestic calls targeted at various groups of researchers, international calls launched by NCN in bi- and multilateral cooperation with foreign research-funding agencies, as well as a number of multilateral programmes launched by international consortia of which the Centre forms part – such as ERA-NETs.

Proposals for domestic and bilateral calls launched by NCN may be submitted in three domains: Arts, Humanities and Social Sciences, Physical Sciences and Engineering, and Life Sciences. Researchers may either submit proposals on behalf of their respective institutions (e.g. universities, institutes of the Polish Academy of Sciences, research institutes) or apply for funding as physical persons. Most funding schemes also provide resources for the purchase of research equipment, with the exception of large research infrastructure. Funding is awarded to the finest basic research projects, conducted by Principal Investigators able to demonstrate the required research experience and capability.

A bottom-up approach is introduced in all calls for proposals. Apart from QuantERA, there are no specific instruments to support Quantum Technology topics. QT funding comes from the success of the researchers in various calls, based on the outstanding quality of the projects.

Research priority areas in Quantum Technology

In 2018, two research units focused on Quantum Technologies were created: International Centre for Theory of Quantum Technologies (ICTQT) at the University of Gdańsk; Quantum Optical Technologies (QOT) at University of Warsaw.

The priority research area of ICTQT concerns the fundamental aspects of quantum physics, with an emphasis on cybersecurity. On the other hand, the priorities of QOT are mainly within quantum optical technologies, with a focus on communication. The research in QOT is more experimental in comparison with ICTQT, which conducts theoretical research. As a complementary action to the above, in 2019, a large consortium focused on quantum computation and algorithms received substantial funding to realize the project entitled "Near-term quantum computers, optimal implementations and applications". The consortium comprises various research teams from the Jagiellonian University (Kraków), Center for Theoretical Physics PAS in Warsaw and the Institute of Theoretical and Applied Informatics PAS in Gliwice.

Quantum Technology funding within organisation

Since there is no specific QT programme, an estimation of the total amount of financial support for projects related to Quantum Technologies had to be approached by drawing the specific projects from the NCN database. Between 2011 and 2019, the total value of projects related to the field of Quantum Technologies funded by NCN reached approx. 43 million PLN (with approx. 9.7 million PLN through the QuantERA programme).

Quantum Technology funding at national level

Currently, there is no dedicated national funding strategy devoted to Quantum Technologies, however, various actions are being taken to propose a national "research agenda" for this topic in the future. At the moment, research proposals falling into the category of Quantum Technologies can be submitted to most of the standard funding schemes open to all disciplines of science.

National Quantum Technology research community

The National Quantum Information Centre (KCIK)[35] is where a substantial proportion of the broad research community focused on Quantum Technology-related topics is organised. The scale of each of the three super-grants is comparable to a small research centre.

35. https://kcik.ug.edu.pl/

Contact information

QuantERA

Sylwia Kostka
Sylwia.Kostka@ncn.gov.pl

Quantum Community Network

Łukasz Rudnicki
Lukasz.Rudnicki@ug.edu.pl

Marcin Pawłowski
Marcin.Pawlowski@ug.edu.pl

Narodowe Centrum Badań i Rozwoju: The National Centre for Research and Development (NCBR)

Funding instruments

The mission of the National Centre for Research and Development (NCBR) is support for the Polish research units and enterprises in developing their ability to create and use solutions based on scientific research results in order to encourage development of the economy and to the benefit of society. Quantum Technology research is funded through thematic calls/programmes. Calls are targeted at specific goals or themes, using a top-down approach.

There are no specific funding programmes to promote young scientists in Quantum Technologies, but programmes like POWER, POIR are those in which young scientists can submit projects on Quantum Technologies.

Research priority areas in Quantum Technology

Quantum communication, Quantum computation, Quantum information sciences, Quantum metrology sensing and imaging – cryptology are considered as priority areas. There is no research agenda for Quantum Technologies.

Quantum Technology funding within organisation

The estimated amount of funding into QT per year is less than €1 million of project funding. It is not known if the budget will be increased in the next three years.

NCBR participated in QuantERA calls in 2017 and 2019 and is planning to take part in two calls of QuantERA II ERA-NET Cofund with Budget: €1 million per each call for the topic: applied quantum science.

Quantum Technology funding at national level

In Poland, QT research is supported by National Science Centre Poland (NCN).

Contact information

QuantERA

Krystyna Maciejko
Krystyna.Maciejko@ncbr.gov.pl

Quantum Community Network

Łukasz Rudnicki
Lukasz.Rudnicki@ug.edu.pl

Marcin Pawłowski
Marcin.Pawlowski@ug.edu.pl

PORTUGAL

Fundação para a Ciência e a Tecnologia : Foundation of Science and Technology (FCT)

Funding instruments

Quantum Technology research is funded through regular national open calls. There are no specific programmes related to Quantum Technologies, except QuantERA.

Research priority areas in Quantum Technology

There are no specific priority areas related to Quantum Technologies. There is no national or regional research agenda for defining priority areas in Quantum Technologies.

Quantum Technology funding within organisation

There is no specific information available on the funding into Quantum Technologies within FCT. It is not known if funding for Quantum Technology will be increased in the coming years. There is no specific funding programme on Quantum Technologies.

Quantum Technology funding at national level

There is no information available any other national public or private research funding bodies supporting the research projects related to the areas of Quantum Technologies.

National Quantum Technology research community

Portugal has a small research community in Quantum Technologies.

Contact information

QuantERA

Germana Santos
Germana.Santos@fct.pt

Quantum Community Network

Yasser Omar
Yasser.Omar@tecnico.ulisboa.pt

ROMANIA

Unitatea Executivă pentru Finanțarea Învățământului Superior, a Cercetării, Dezvoltării și Inovării: Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI)

Funding instruments

The Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI) funds Quantum research through national open calls – open to all scientific domains, with no restriction on theme. Calls are open to types of institutions with R&D activities within their domains. There are 4 programmes administrated (partially or totally) by UEFISCDI:

- Development of the National Research and Development System – composed of instruments dedicated to the development of human resources, infrastructures and specialised institutions;
- Increase the Competitiveness of the Romanian Economy through Research, Development and Innovation – with instruments dedicated to intensifying partnerships for industrial research and experimental development activities;
- European and International Cooperation – with instruments dedicated to supporting international collaboration projects like QuantERA (among others);
- Fundamental and Frontier Research – with instruments dedicated to adding the "frontier" dimension to Romanian fundamental research, by obtaining top scientific and technological results, with perspectives marketing.

Most of the calls are bottom-up (there is just an instrument "Solutions" which is top-down but with no priority for Quantum Technology), with no specific instruments to support Quantum Technology topics. There is an increased interest in QT topics, considering the increasing interest in QuantERA. Romania does not have a national strategic research agenda for Quantum Technologies.

Research priority areas in Quantum Technology

In general (except for one instrument) no priorities area are defined, all calls are open to all scientific domains.

Quantum Technology funding within organisation

Since there is no specific QT programme, an estimate of the financial support for QT projects is difficult to obtain. Nevertheless, based on a brief analysis, the estimated funding into Quantum Technologies per year is <€1 million. It is not known if funding for Quantum Technologies will be increased in the coming years.

Quantum Technology Programmes

As we do not have a specific Quantum Programme, Quantum research is supported through participation in the QuantERA network and through the annual calls (open to all topics).

Quantum Technology funding at national level

Other funding bodies supporting research projects related to QT are the Ministry of Education and Research, and the Institute of Atomic Physics, but there is no research call specifically dedicated to the area of Quantum Technologies.

National Quantum Technology research community

Most of the Quantum Technology research in Romania is concentrated in national institutes and universities (Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), National Institute for Laser, Plasma and Radiation Physics (INFLPR); National Institute for R&D in Microtechnologies (IMT); University Politechnica of Bucharest (UPB); National Institute for R&D of Isotopic and Molecular Technologies (INCDTIM-Cluj).

Contact information

QuantERA

Nicoleta Dumitrache
Nicoleta.Dumitrache@uefiscdi.ro

Quantum Community Network

Radu Ionicioiu
R.Ionicioiu@theory.nipne.ro

SLOVAKIA

Slovenská akadémia vied: Slovak Academy of Sciences (SAS)

Funding instruments

Quantum Technology research is only funded through participation in QuantERA. There are no specific funding programmes to promote young scientists in Quantum Technologies, but in programmes like; Schwarz stipend (annually); MOREPRO fellowship (one call); SASPRO fellowship (EC cofund scheme) projects on Quantum Technologies can be submitted.

Research priority areas in Quantum Technology

There are no specific priority areas related to Quantum Technologies. There is no national or regional research agenda for defining priority areas in Quantum Technologies.

Quantum Technology funding within organisation

The estimated amount of funding into QT per year is less than €1 million of project funding. No budget increase is expected in the next three years. There is no specific funding programme on Quantum Technologies at the moment or planned.

Quantum Technology funding at national level

No specific support scheme exists for national public or private research funding bodies supporting research projects in Quantum Technologies.

National Quantum Technology research community

The activities of the community are coordinated by the national platform QUTE .SK[36] that is in communication with all potential funding bodies (both state and private ones). The platform was established legally on the request of the Ministry of Education and includes partners from 8 academic institutions. Strategic documents presenting research plans and activities were prepared and submitted to governmental bodies in 2018. The three main pillars are the establishment of a quantum research institute (with specified research goals), a quantum education centre (coordinating Quantum Technology study programmes, but also organising international educational activities) and a quantum communication infrastructure[37]. The expertise covers theoretical quantum information processing and superconducting Quantum Technologies.

36. http://qute.sk/
37. http://quapital.eu/

Contact information

QuantERA

Martin Novak
MNovak@up.upsav.sk

Quantum Community Network

Mario Ziman
Mario.Ziman@savba.sk

SLOVENIA

Ministrstvo za izobraževanje, znanost in šport: Ministry of education, science and sport (MIZIS)

Funding instruments

The Ministry of Education, Science and Sport is funding quantum research through ERA-NET QuantERA. The research agency is part of the Ministry that does not directly fund quantum research through national calls, but researchers can apply in the field of computer science, physics, etc. There is no specific funding programme for young scientists.

Research priority areas in Quantum Technology

The calls are open to all scientific domains, with no priority areas defined.

Quantum Technology funding within organisation

The Ministry of Education, Science and Sport has funded projects related to the field of quantum research with around €300k for three years. In the coming years we have a plan to establish a quantum field at the national agency and also to increase the budget for quantum research. At the moment there is no dedicated funding programme for Quantum Technology research.

National Quantum Technology research community

The Center for Quantum Technology Slovenia[38] is based at the Institute of Josef Stefan. Main activities are popularisation of QT: lectures, posters, news.

38. http://www.qutes.si/

Contact information

QuantERA

Andrej Ograjensek
Andrej.Ograjensek@gov.si

Quantum Community Network

Martina Knavs
Martina.Knavs@ijs.si

SPAIN

Agencia Estatal de Investigación: State Research Agency (AEI)

Funding instruments

The Spanish national funding agency Agencia Estatal de Investigación (AEI) is funding quantum research through national open calls/programmes. The national calls are open to all scientific domains, with no restrictions on theme except on the organisational level. Those calls are open for non-profit research organisations and collaborative projects. There are four main types of research projects at the national level:

- Excellence science projects. The goal is to generate new general scientific knowledge;
- Challenge research projects. The goal is to support research applied/oriented to solve societal and industrial challenges;
- Young researcher projects. These projects are directed by non-staff young researchers (postdocs) affiliated to a public research organisation and supported by a research group. The goal is to support young researchers with innovative research lines;
- Public/private collaborative projects. These kinds of project are focused on the specific research demanded by the R+D+I departments of companies. Several partners can be funded but at least one company/industrial partner must be involved in the consortium. This is the only type of project that involves industrial partners.

In addition to these research project calls there are other relevant calls that need to be considered:

- International joint programming. The goal is to support the international cooperative projects like those in QuantERA among others;
- Ramon y Cajal programme. The goal is to support (5 years funding) the incorporation of excellent senior postdocs in national labs;
- Scientific equipment. The goal is to support the acquisition of new scientific equipment.

All the calls and programmes are bottom-up. There are no specific instruments to support Quantum Technology topics. QT funding comes from the success of the researchers in the different calls based on the quality of the projects.

Research priority areas in Quantum Technology

The national calls are open to all scientific domains, with no priority areas defined.

Quantum Technology funding within organisation

Since there is no specific QT programme, an estimation of the financial support for projects related to Quantum Technologies has been approached by selecting the projects from the AEI database. Between 2015 and 2017, AEI has funded projects related to the field of Quantum Technologies with around €20 million. Not included in this estimation are the salaries of permanent staff involved in the research projects. Typically, the funding amount will multiply by 2 including the costs of the involvement of permanent staff.

Quantum Technology funding at national level

In Spain, QT research can also be supported by the Centre for the Development of Industrial Technology (CDTI) at the national level. This agency specifically funds industrial partners. There are several other regional funding bodies, e.g. in the Basque Country, that can fund QT related projects. In the Autonomous Community of Madrid, the regional government has funded the QUITEMAD network on Quantum Information and Quantum Technologies with a total of €2.4 million in the period 2014-2022. The Government of Catalonia has also funded two regional programmes, QUANTUMCAT (€2 million) and SMARTCAT (€1 million). The Regional Government of Aragón has funded QT-related programmes through their project, groups and PhD grant schemes, for a total of about €0.4 million. In all three cases, the funding was supported by the RIS3 (Research and Innovation Smart Specialisation Strategy) scheme.

National Quantum Technology research community

In Spain, there is a worldwide recognised community of researchers devoted to theoretical and applied work. There is also a significant community of experimental groups. Spain contributes to the European challenges with an outstanding scientific community. Spain supports the generation of national Quantum networks as the Quantum Information Network in Spain (RICE). This network includes almost all top institutions involved in the quantum field. A platform for Quantum technologies has also been recently created in the CSIC, the largest research institution in Spain, to motivate transfer and collaboration between academia and industry. The CSIC itself has become a member of the IBM-Q network.

Contact information

QuantERA

Watse Castelein
era-ict@aei.gob.es

Quantum Community Network

Antonio Acin
Antonio.Acin@icfo.eu

Juan José Ripoll
JJ.Garcia.ripoll@csic.es

SWEDEN

Vetenskapsrådet: Swedish Research Council (VR)

Funding structure

The Swedish Research Council (VR) is Sweden's largest governmental research funding body, and supports basic research of the highest quality within all scientific fields.

VR supports Quantum Technology research through open calls/programmes. The calls are open to all scientific domains, with no restrictions on theme.

Priority areas

VR evaluates each open proposal on research quality and does not prioritise any specific area.

QT funding within the Research Funding Organisation (RFO)

There is no specific information available on the funding into Quantum Technologies within VR. It is not known if funding for Quantum Technology will be increased in the coming years.

QT funding by other bodies than the RFO

The Knut and Alice Wallenberg Foundation[39]; VINNOVA, Swedish Foundation for Strategic Research

Quantum Technology research community

The most important Swedish research programme is the Wallenberg Centre for Quantum Technology (WACQT), which is a 12-year SEK 1 billion research programme that aims to take Swedish research and industry to the forefront of quantum technology. Through an extensive research programme, the aim is developing and securing Swedish expertise within the main areas of Quantum Technology: Quantum Computing and Simulation, Quantum Communications and Quantum Sensing. The main project is to develop a high-end quantum computer that can solve problems far beyond the reach of the best conventional supercomputers.

39. https://kaw.wallenberg.org/

Contact information

QuantERA

Tomas Andersson
Tomas.Andersson@vr.se

Quantum Community Network

Goran Wendin
Goran.Wendin@chalmers.se

SWITZERLAND

Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung: Swiss National Science Foundation (SNSF)

Funding structure

The SNSF's strategic goals are to

- support high-quality research as well as researchers in their quest for excellence;
- bring research funding closer into line with the researchers' needs;
- support the spread of knowledge in society, the economy and politics and demonstrate the value of research.

Quantum Technologies (QT) research is funded in two ways.

1. Thematic calls/programmes with a specific goal (national and international programmes).
2. Calls/programmes open to all scientific domains (bottom-up approach) with no restrictions on themes. This is the main funding scheme of the SNSF and includes national projects as well as international ones (Lead-Agency scheme). Part of this funding is dedicated to QT.

Priority areas

Since the core spirit of the SNSF is bottom-up, it does not directly specify priority areas. The latter are rather defined by the strategic community-driven orientations. Over the last 5 years, among the main QT-targeted areas, quantum information sciences and quantum computation have received more attention compared to quantum communication and quantum metrology, sensing and imaging.

From the point of view of thematic programmes, the SNSF has created "QSIT – Quantum Science & Technology" as one of the National Centres of Competence in Research (NCCRs). Its goals range from present and future engineering applications, such as quantum cryptography and quantum computation, to the investigation of new paradigms for fundamental physics such as topological states of matter.

Quantum Technology funding within the Research Funding Organisation

The funding dedicated to QT varies over the years (bottom-up funding). In recent years, regular SNSF calls have dedicated about €5-10 million per year to this. Details on past and currently funded projects in QT can be found on the open SNSF database P3.[40]

The National Centre of Competence in Research (NCCR) "QSIT – Quantum Science & Technology" is funded through grants awarded by the SNSF, but also from other sources, in total for 12 years (2010-2022). The home institutions involved in the NCCR also contribute a substantial amount. The available overall budget of the NCCR is further increased by monetary contributions from the project participants and third-party funds, which are generally invested by industrial companies. The SNSF is financing the NCCR QSIT in its third 4-year funding period. The total budget for 2018-2021 is 50 571 882 CHF of which 14 950 000 CHF is granted by the SNSF.

Quantum Technology funding by other bodies than the RFO

In Switzerland, QT research is also supported by Innosuisse, the Swiss innovation agency funding innovation-oriented research. Several quantum centres with local funding exist (or will soon open) at several Swiss Universities, such as the University of Basel, the University of Geneva and ETH Zurich.

Quantum Technology research community

Overall, 44 research groups in Switzerland are part of the NCCR QSIT. In addition, there are about 10-20 groups at various public institutions working in Quantum Science and Technology. Meanwhile, several quantum startups have emerged from the NCCR QSIT (e.g. IRSweep, QZabre, Qnami).

Starting from 1st August 2020, a new NCCR "Spin"[42] has been launched with funding from SNSF. This research project will focus on using spin qubits in silicon for a future quantum information processor. About 25 research groups from all over Switzerland will be involved.

40. http://p3.snf.ch/
41. https://www.innosuisse.ch/
42. http://www.snf.ch/en/researchinFocus/nccr/spin/Pages/default.aspx

Contact information

QuantERA
Ahmad Zein Assi
quantera@snf.ch

Quantum Community Network
Klaus Ensslin
Ensslin@phys.ethz.ch

TURKEY

Türkiye Bilimsel ve Teknolojik Araştırma Kurumu: Scientific and Technological Research Council of Turkey (TUBITAK)

Funding instruments

Quantum Technology research in TUBITAK is funded through bottom-up funding programmes.

Research priority areas in Quantum Technology

Quantum Technologies are addressed in the national call programme of TUBITAK as a priority area in 2020. Subtopics of research to be funded are fundamental quantum research, quantum computing systems and quantum optics.

Quantum Technology funding within organisation

The estimated amount of funding into QT per year is €2-5 million of project funding. There is no specific plan to increase funding for Quantum Technologies in the next three years.

There is no dedicated funding programme on Quantum Technologies. At this moment there are no plans to launch a programme.

Quantum Technology funding at national level

There is no information available on other national public or private research funding bodies supporting research projects in Quantum Technologies.

National Quantum Technology research community

The Quantum research community in Turkey differsr on the levels of experimental and theoretical researchers. The experimental community is strongly intertwined with optics and photonics research communities, where the connection is usually through quantum optics-related research topics. This section of the community is mainly interested in quantum cryptography, communication and sensing. Researchers focusing on the theoretical aspects of quantum research is the second main section of the community in Turkey. Studies in this group are very diverse, covering research topics from the discovery of new quantum algorithms to applications of quantum thermodynamics in the space environment. Experimental groups tend to be more conservative and risk-averse in terms of pursuing emerging research topics. Theoretical researchers either work closely with experimental groups in order to advance their understanding of the topics or work independently and focus on newly emerging fields. One of the main characteristics of the quantum research community in Turkey is the low levels of collaboration when compared to colleagues from Europe or the US.

The main national quantum research networks in Turkey are KOBİT (Quantum Optics and Information Meeting) and TÜBİTAK Research Institutes such as TBAE (Research Institute for Fundamental Sciences), UME (National Metrology Institute) and BİLGEM (Informatics and Information Security Research Centre). KOBİT is a series of conferences and workshops that have been organized in different cities. The first meeting was held in 2016. TÜBİTAK is the main scientific body in Turkey, and different institutes under it are focusing on different aspects of Quantum Technologies. They organise workshops, become partners in national and international projects (such as QuantERA), and mainly act as signalling beacons for national policies in Quantum Technologies.

Contact information

QuantERA

Serkan Üçer
ncpfet@tubitak.gov.tr

Quantum Community Network

Zafer Gedik
Gedik@sabanciuniv.edu

Atilla Hasekioğlu
Atilla.Hasekioglu@tubitak.gov.tr

UNITED KINGDOM

United Kingdom Research and Innovation (UKRI)

UK Research and Innovation

Funding instruments

UK Research and Innovation brings together the seven Research Councils, Innovate UK and Research England. Quantum technology in the UK is mainly funded through the UK National Quantum Technology Programme, and is delivered by the following funding partners: Engineering and Physical Sciences Research Council (EPSRC), Science and Technology Facilities Council (STFC), Innovate UK (IUK), Department for Business, Energy and Industrial Strategy (BEIS), National Physical Laboratory (NPL), Government Communications Headquarters (GCHQ), and the Defence Science and Technology Laboratory (DSTL).

Research priority areas in Quantum Technology

Priority research areas within the programme broadly cover four thematic areas within Quantum Technologies: sensing and metrology, computing and simulation, secure communications and imaging.

Quantum Technology funding within organisation

The UK programme is expected to reach a £1 billion investment in the 10-year period from 2014. The programme entered its second phase in 2019.

Quantum Technology Programmes

During the first phase of the National Quantum Technologies Programme[43] (2014 – 2019), EPSRC funded a national network of Quantum Technology Hubs through a £120 million investment in four hubs over five years. These were to harness the UK's strengths in quantum science by turning this into strength in Quantum Technologies. As part of their investments in the second phase of the National Programme, EPSRC has refreshed the Quantum Technology Hubs at the end of 2019, with a £94 million investment in four hubs over five years, to maintain the technological research leadership that the UK has established in Quantum Technologies through the UK National Quantum Technologies Programme.

The 2018 call for EPSRC's Centres for Doctoral Training saw several awards were made that support skills development within the field of Quantum Technologies, including the EPSRC Centre for Doctoral Training in Delivering Quantum Technologies (University College London)[44], and the EPSRC Centre for Doctoral Training in Quantum Engineering (University of Bristol)[45].

Quantum Technology funding at national level

The Industrial Strategy Challenge Fund – QT (IUK)

As part of the UK national programme's efforts to support the industrialisation of Quantum Technologies and the advancing of fundamental quantum science, the Industrial Strategy Challenge Fund or ISCF has also launched the Commercialising Quantum Technologies challenge[46] by investing around £153m in Quantum Technologies supported by a further £205 million fund from industry helping turn quantum science into quantum engineering and to provide essential support to businesses developing quantum-enabled products by removing barriers to productivity and competitiveness.

43. http://uknqt.epsrc.ac.uk
44. https://www.ucl.ac.uk/quantum/study-here/cdt-delivering-quantum-technologies
45. http://www.bristol.ac.uk/quantum-engineering/
46 http://ukri.org/quantum-tech

Quantum Technologies for Fundamental Physics Programme – (STFC and EPSRC)

This programme represents an opportunity to build on the UK's current capabilities in physics and Quantum Technology and establish a network of practitioners working in this area. It is envisaged that the programme will widen the uptake of Quantum Science and Quantum Technology throughout the science research base further increasing the reach and utilisation of the advances made possible with this technology. The aim of this experimental programme is to demonstrate how the application of Quantum Technologies will advance the understanding of fundamental physics questions. The programme has total funds of up to £40 million. The first call closed in December 2019.

National Quantum Computing Centre

UK Research and Innovation, through the EPSRC and the STFC, has established the National Quantum Computing Centre (NQCC) in 2020. The NQCC will build the UK's capability to be at the forefront of quantum computing, delivering greater prosperity and security advantages for the UK. The NQCC will be a dedicated national centre with the aim of working towards fully scalable, fault tolerant, general purpose quantum computing.

UK-Canada call on Quantum Technologies

At the international level, IUK and the Natural Sciences and Engineering Research Council of Canada (NSERC) have recently partnered to launch a call in summer 2020 for research proposals on Quantum Technologies following the 2018 global expert mission led by the UK (KTN – Knowledge Transfer Network – and UKRI) to Canada. This call will allow for collaboration between leading-edge scientists and potential innovative users, from industry and/or government sectors to accelerate the development of Quantum Technologies.

Contact information

QuantERA

Marzena Szymańska
M.Szymanska@ucl.ac.uk

Pieter Kok
P.Kok@sheffield.ac.uk

Mehul Malik
M.Malik@hw.ac.uk

Florian Mintert
F.Mintert@imperial.ac.uk

Quantum Community Network

Ian Walmsley
Ian.Walmsley@physics.ox.ac.uk

Kai Bongs
K.Bongs@bham.ac.uk

Conclusion

Building on the experience in successfully providing the research community with a coordinated Europe-wide approach to support cutting-edge research in QT, with EU support, the QuantERA consortium will continue its activities and develop them even further through the upcoming QuantERA II ERA-NET programme.

Following the success of the previous two calls for proposals, a transnational co-funded call with a planned budget of over €40 million will be launched in 2021.

QuantERA II will seek to effectively liaise with the QT Flagship and other stakeholders in the field of QT research to make the best use of the collective European experience in QT research funding, as well as address the gender imbalance in QT research and spread the research excellence across the European Research Area. A range of additional activities will be integrated into the launch of the co-funded call, including strengthening the multilateral dialogue with policy makers regarding the design of future funding instruments, stimulation of networking and exchange of best practices, as well as continuation of mapping of public QT policies in Europe. The QuantERA II consortium, including 38 partners from 30 countries, keeps on reaching further – hence, this report will be updated regularly to reflect the most up-to-date situation.

The QuantERA II programme will continue to provide a structured framework to coordinate national and regional research programmes in QT. We invite you to reach out and stay connected with us to know more about the plans and visions for the future of QT research: **www.quantera.eu**

Acknowledgements

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The report will be updated regularly and as needed.

For more information, please refer to the QuantERA website:
www.quantera.eu

Sylwia Kostka, Programme Coordinator, NCN:
Sylwia.Kostka@ncn.gov.pl
Konrad Banaszek, Scientific Coordinator, NCN:
Konrad.Banaszek@ncn.gov.pl
Watse Castelein, European Project Manager, AEI:
Watse.Castelein@cienciasinformacion.fecyt.es

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