Patent insight report

Quantum technologies and space

Europäisches Patentamt
European Patent Office
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ESPI
European Space Policy Institute

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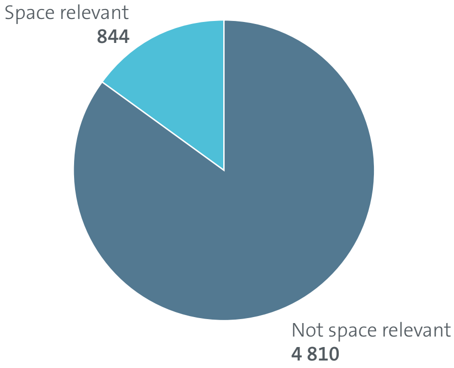
Executive summary

This study, the second in the series of collaborative patent insight reports by the European Patent Office (EPO) and the European Space Policy Institute (ESPI) in collaboration with the European Space Agency (ESA), examines global patent filing trends (2001-2020) in the domain of space applications of quantum technologies (QT).

Quantum and space domains have both become strategically important technology sectors for major powers around the world, including for European countries and the European Union (EU). Using QT in the space environment is a very specific use of the technology but one that is being explored more and more, as evidenced by several recent satellite demonstration missions carrying quantum cryptography payloads.

Primary uses of QT in space are in secure communications, in time and frequency transfer, and in Earth sensing and observation. In the patent filing analysis, the study considered three key QT that enable these main applications:
— quantum key distribution
— cold atom clocks
— cold atom interferometers

Patent families in quantum key distribution, cold atom clocks and cold atom interferometers



The analysis of global patent filing statistics highlighted the following key trends:

Space applications of QT are a fast-growing domain, with patent filings increasing by more than 400% over the last five years.

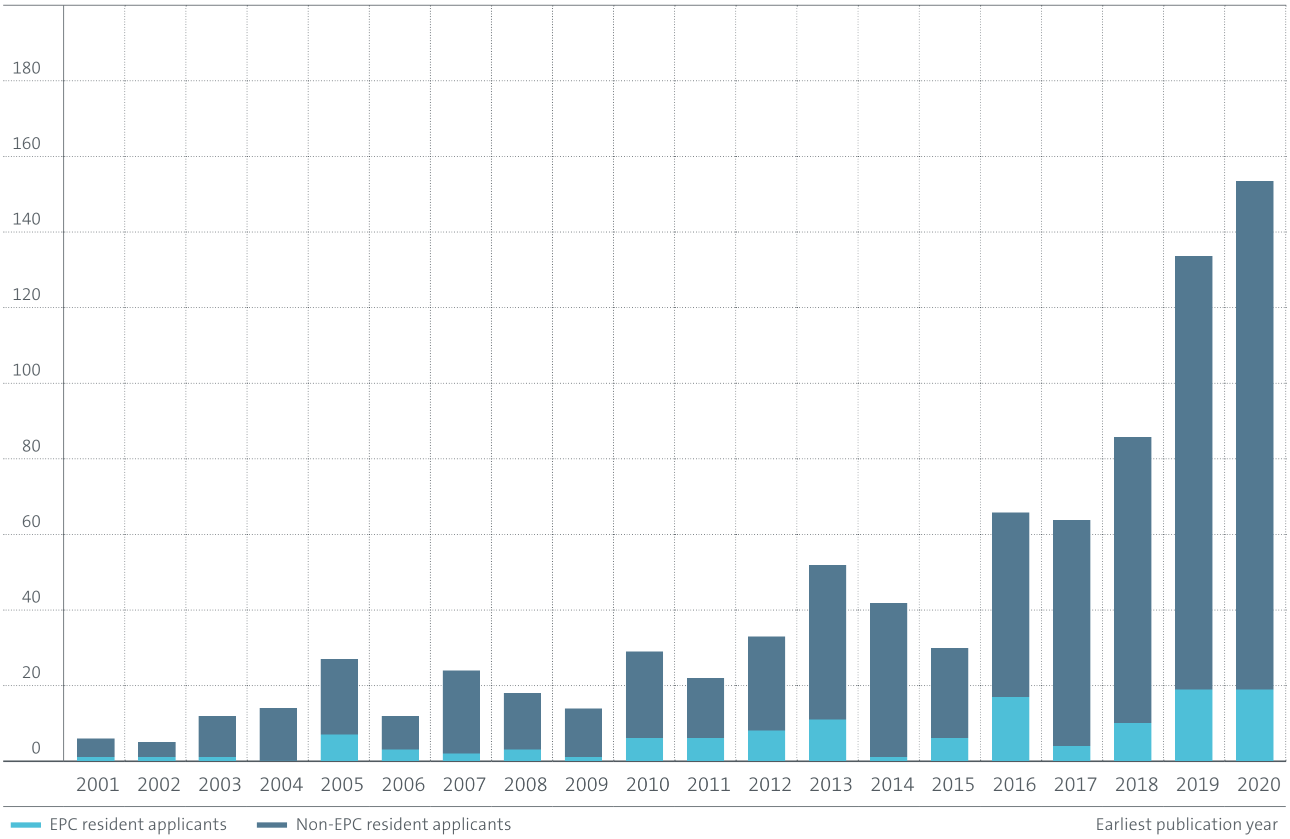
This growth is driven primarily by innovation in quantum key distribution, which accounted for the majority of the analysed dataset (78%).

At the same time, space applications of QT remain a niche segment, representing only a fraction of the overall QT domain.

Most space-related QT innovations originate outside Europe, with the US and China leading the global patent filings.

The majority of patent filings in quantum key distribution, cold atom clocks and cold atom interferometers are not from the same key players, pointing to a high level of specialisation and limited synergies.

Trends in space-related QT patent families



The growing political interest in QT and their applications around the globe, including in the space sector, is fuelling innovation in the field and generating tangible opportunities for new inventions. In Europe, QT and space applications such as space-based quantum key distribution have been recognised as a disruptive technology sector with fundamental implications for society and the economy as a whole. According to patent filing statistics, however, Europe is not yet a forerunner in space-related QT innovation. This could change in the future with the recent introduction of major programmes such as the European Quantum Communication Infrastructure (EuroQCI), which is aimed at developing a European infrastructure for quantum communication using quantum key distribution and should include a significant space element.

1. Introduction

1.1 Quantum technologies

Research in the field of quantum physics has been ongoing for decades, contributing to the development of some of the core technologies underpinning modern society such as lasers or transistors. In recent years, the commercial potential of the more unusual properties of quantum physics, like quantum superposition and entanglement, have increasingly taken centre stage. As QT exploit the laws of quantum physics, they are capable of addressing some of the biggest challenges facing today's digital era, such as secure communications, computing power and sensor accuracy.

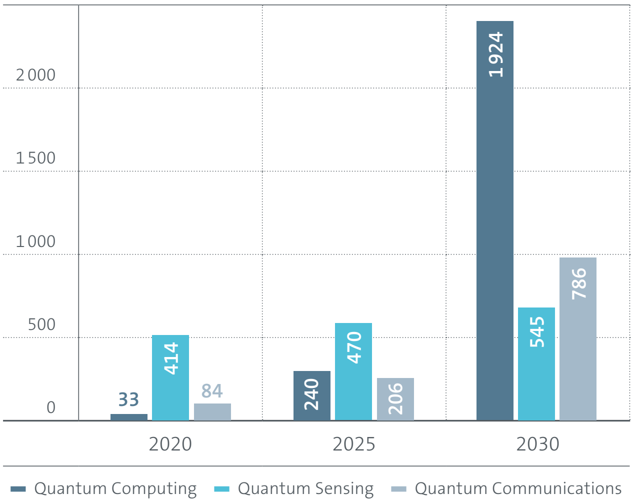
QT can be divided into four different areas:

- **Quantum communication** uses quantum states of photons and appropriate protocols to transmit data securely.
- **Quantum simulation** uses controlled quantum systems to replicate and test models of less accessible quantum systems.
- **Quantum computing** exploits quantum effects to increase computational power.
- **Quantum metrology and sensing** use the properties of coherent quantum systems and their interactions with the environment.

The 2010s saw several major government initiatives and programmes relating to QT launched around the world, providing billions of euros for basic and advanced research, including for space applications. All these initiatives were aimed at accelerating the transition from academic research to tangible applications.[1] Beyond the great socio-economic value of quantum applications, governments also recognise QT as a strategic capability due to their potential use in defence, secure communications and increased cybersecurity.[2]

As at January 2021, 17 countries have introduced some form of national initiative or strategy to support QT research & development (R&D), 3 have strategies in various stages of development and 12 others have significant government-funded or government-endorsed initiatives.[3] A detailed list of public QT initiatives is provided below in the section "List of major public QT initiatives".[4]

Growth forecastfor QT markets in million USD



Credit: Yole Development

The private sector has also massively invested in quantum-related R&D over the last decade, particularly in quantum computing.[5] More and more in-house investments totalling billions of dollars are also being announced by global tech giants (e.g. Google, Microsoft, IBM, Alibaba, Toshiba), while a growing number of QT start-ups are attracting private investors. Global private investment in QT grew significantly between 2012 and 2018, reaching almost half a billion dollars in 2017 and 2018 combined.

1.2 The space sector

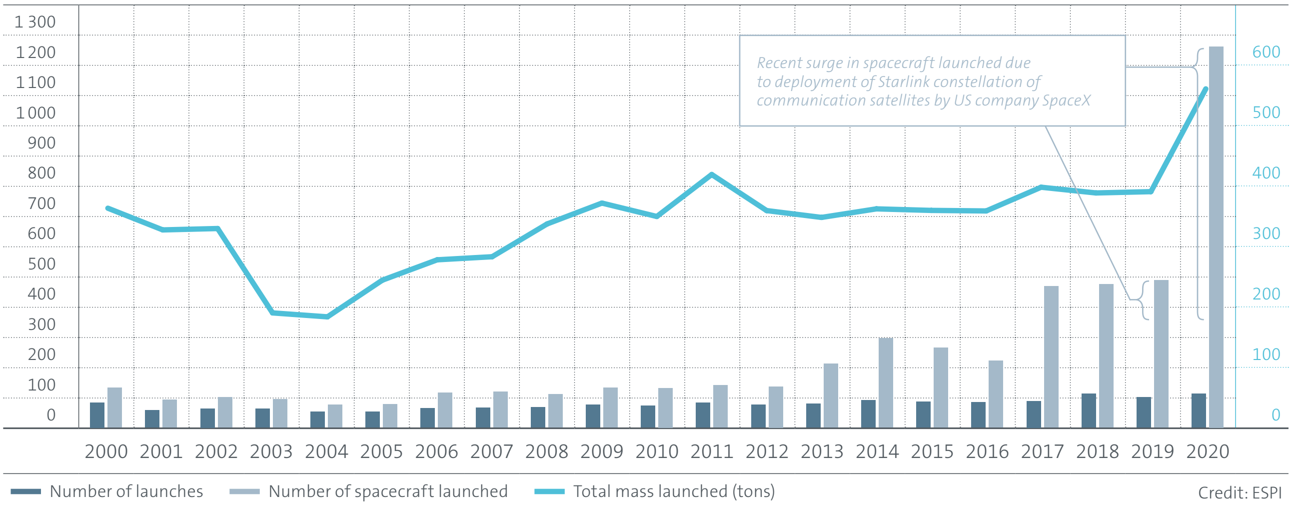
Global space activity has intensified and diversified considerably over the past decade. While only 110 spacecraft were launched on average per year between 2000 and 2013, recent years have seen a paradigm shift, especially with the launch of new satellite "mega-constellation" projects. A new record was set in 2020, with 1 266 spacecraft launched into outer space.[6] As a direct result of this surge, the number of operating satellites has doubled in less than a decade.

Technological innovations are changing the way space is accessed and utilised and are enabling new missions and applications. Many new players and countries are now focusing on space, with private capital flows into the space sector skyrocketing. Today's space industry is an ever more service-driven domain where a growing number of public and private players across all continents engage in a variety of activities for scientific, military and commercial purposes, ranging from space exploration and human spaceflight to communication and navigation enabled by satellites.

1 https://publications.jrc.ec.europa.eu/repository/handle/JRC115251
2 https://apo.org.au/node/305274
3 https://cifar.ca/wp-content/uploads/2021/04/quantum-report-EN-10-accessible.pdf
4 Overall, the majority of current global quantum-related funding and R&D appears to be in the field of quantum computing.

5 https://www.nature.com/articles/d41586-019-02935-4
6 https://espi.or.at/downloads/send/79-espi-yearbook/573-espi-yearbook-2020

Number of launches, number of spacecraft launched and total mass launched in tons



1.3 Space applications of QT

Quantum and space domains have both become strategically important technology sectors for major geopolitical powers around the world, including for European countries and the EU. Using QT in the space environment and on-board space-based platforms is a very specific use of the technology but one that is being explored more and more.

The relevance of space applications of QT has been investigated and demonstrated in recent years with the success of several dedicated satellite missions carrying QT payloads, such as China's Micius satellite in 2016 or the SpooQy-1 mission by the National University of Singapore in 2019. Numerous other satellite projects exploring the potential of space-based QT for distributing keys in the field of cryptography are under development, e.g. at the ESA (SAGA, Quartz or QKDSAT as a partnership project with Arqit) and in the UK (ROKS), Germany (QUBE) or Canada (QEYSSAT).

In addition, recent research and space-based experiments[7] indicate that a successful uptake of QT in space could significantly enhance certain activities such as positioning, navigation and timing, or satellite gravimetry.

A review of the available literature and public QT initiatives around the world reveals three core application domains for QT in space and their enabling technologies: [8]

In **secure communications**, space-based quantum key distribution and related technologies (e.g. entangled photon sources, single-photon detectors, quantum random number generators) will play a major role as fibre-based quantum key distribution has major signal and security limitations which currently prevent long-distance key distribution for encrypting communication links.

In **time and frequency transfer**, a greater uptake of QT in the space environment is expected in new-generation cold atom clocks for improved positioning, navigation and timing applications. QT makes it possible to significantly boost time and frequency transfer performance and potentially enable new applications.

In **Earth sensing and observation**, R&D of space-based QT sensors is targeting multiple applications. Current priorities seem to be cold atom interferometry for gravimetry and geodesy purposes. Other research avenues include quantum-enhanced radiofrequency or optical signal processing for monitoring spectrum utilisation, or space-borne quantum radars for various risk-detection and early-warning purposes.

Some of these applications have a strategic importance for major global powers, including Europe. With R&D efforts in other countries gathering pace and cyberspace becoming increasingly hostile, the EU has taken concrete steps to boost

[7] For instance, the Chinese demonstration of a space-based cold atom clock on board the now-defunct Chinese space station Tiangong-2 in 2016 or the installation of a JPL-developed experimental facility "Cold Atom Laboratory" on the International Space Station in 2018.

[8] A White Paper on Quantum Technologies in Space published by the Quantum Space Network in 2019 (http://www.qtspace.eu/sites/testqtspace.eu/files/other_files/QT%20In%20Space%20-%20White%20Paper%20Final_0.pdf) also identified "fundamental physics" as one of the major areas of application for QT in space, underlining the suitability of the space environment for unique experimental tests, in particular with regard to the existence of macroscopic quantum states.

European quantum key distribution capabilities, including with a space component, with a view to developing the EuroQCI, an integrated European infrastructure to support Europe's digital autonomy and sovereignty.[9]

Exploiting QT in space remains technically challenging. For a greater uptake of QT in space, QT concepts will need to be adapted to the particularities and requirements of the operational environment in space (e.g. miniaturisation, greater robustness against cosmic radiation, power consumption requirements).

1.4 The study

By virtue of their respective missions and activities, the EPO, ESPI and ESA share a common interest in the study of patent filing statistics to improve understanding of trends affecting the space sector. In 2020, the EPO and ESPI in collaboration with the ESA published a pilot study[10] to examine patent filing statistics over the last 30 years in cosmonautics, to assess the relevance of that data to the identification of trends in the space sector.

Building on that collaboration, this study by the EPO and ESPI in collaboration with the ESA was launched in 2021, focused on assessing patent filing statistics in the specific domain of space applications of QT. Its primary objective was to examine global movements in patent filings in order to identify major trends in the uptake of QT in the space environment. To do so, the study has used various resources, including EPO patent databases and registers, ESPI publications, ESA technical expertise and other available public reports and scientific articles.

1.5 Using patent information

Patents are exclusive rights that can only be granted for inventions that are novel, inventive and industrially applicable. High-quality patents are assets which can help attract investment, secure licensing deals and provide market exclusivity. Inventors pay annual fees to maintain those patents that are of commercial value to them and protect their inventions from being openly used by others, including competitors, in all protected markets. A patent can be maintained for a maximum of 20 years. In exchange for these exclusive rights, all patent applications are published, revealing the technical details of the inventions in them.

Patent databases therefore contain a wealth of technical information on both patent applications and granted patents, much of which cannot be found in any other source and which anyone can use for their own research purposes. The EPO's free Espacenet database contains more than 130 million documents from over 100 countries, and comes with a machine translation tool in 32 languages. Patent filing statistics provide interesting indicators to measure and examine innovation, commercialisation and knowledge transfer trends. The protection of intellectual property is very well documented in national and international databases and registers, which track bibliographic and legal event data on patent applications.

Dedicated exploitation of these patent databases and registers can reveal new insights into sector trends and support informed decision-making processes. Patents provide means of observing technology trends, key innovators and policies in various jurisdictions. This data can be combined with further public information such as national R&D budgets and specific market studies.

EPO / ESPI

Europäisches Patentamt
European Patent Office
Office européen des brevets

The European Patent Office examines European patent applications, enabling inventors, researchers and companies from around the world to obtain protection for their inventions in up to 44 countries. The EPO is the executive arm of the European Patent Organisation, an international organisation with 38 member states. The EPO's activities and budget are overseen by the Organisation's Administrative Council, which consists of representatives of the member states.

ESPI
European Space Policy Institute

The European Space Policy Institute provides decision-makers with an informed view on mid- to long-term issues relevant to Europe's space activities. It provides recommendations, policy options and forward vision as to how Europe's engagement in space can bring maximum benefit to society. In this context, ESPI acts as an independent platform for developing positions and strategies.

ESA

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The European Space Agency is an intergovernmental organisation with 22 member states. It is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. By co-ordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.

[9] ESPI Brief on Quantum communications: https://espi.or.at/news/quantum-and-space-the-ultimate-solution-to-secured-communications

[10] https://www.epo.org/news-events/news/2021/20210721a.html

1.6 Methodology

The information, data and analysis provided in this study are primarily based on dedicated exploitations of EPO patent databases (e.g. PATSTAT, Global Patent Index (GPI)) and registers covering relevant patent publications between 2001 and 2020. The EPO was responsible for creating the domain-specific queries and the structured dataset for the analysis, with assistance from several ESA experts to identify relevant technologies.

The consolidated patent filing dataset was based on three overarching areas for the primary space applications of QT:

— quantum key distribution
— cold atom clocks
— cold atom interferometers

The data was mined (search queries) and curated by the EPO in line with existing best practices of EPO experts and patent examiners. A specific challenge of this study was additionally identifying and selecting patents from the technology domains that could show clear potential for application in space, in order to compile a meaningful dataset. The selected methodology applied a "space filter" to the general queries, which involves a combination of keywords and classification symbols developed, tested and adjusted for an optimised "hit-to-noise" ratio. Example keywords used were "outer space", "deep space", "satellite" and "microgravity".

Various criteria were also considered for investigating the suitability of the inventions, including miniaturisation, low weight, low power consumption and robustness against launch and cosmic radiation. Inventions addressing these criteria within the technology areas were manually added to the space-related dataset.

Throughout the study, patent filing statistics are addressed at both consolidated level (quantum key distribution, cold atom clocks and cold atom interferometers together) and individually, as appropriate.

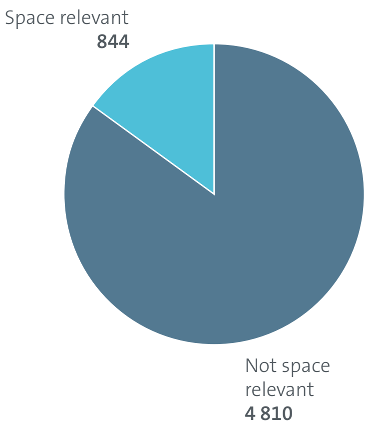
A more detailed methodology and description of the technologies addressed in this study are provided in the supplementary material.[11]

[11] https://www.epo.org/searching-for-patents/business/patent-insight-reports.html

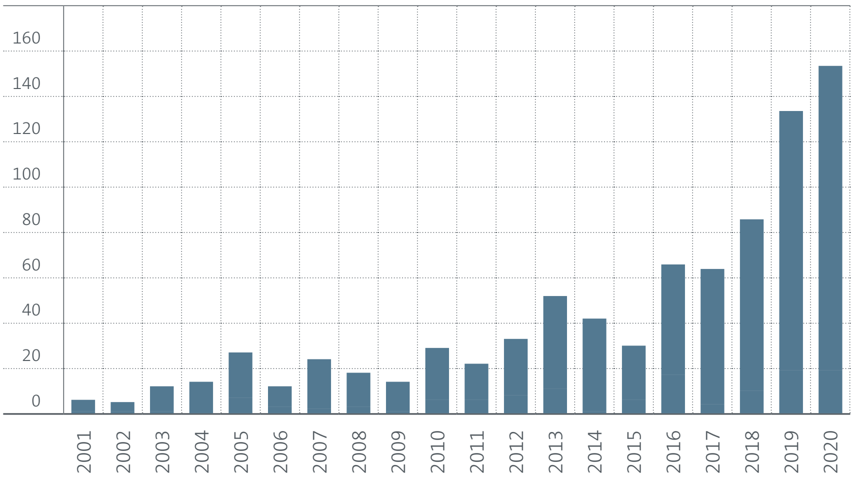
2. Analysis

2.1 A niche field that is rapidly growing

Patent families in quantum key distribution, cold atom clocks and cold atom interferometers



Trends in space-related QT patent families



Out of a total of 5 654 patent families in quantum key distribution, cold atom clocks and cold atom interferometers published between 2001 and 2020, 844 (15%) were space-related. The number of patents has skyrocketed over the last decade, with the annual number of inventions submitted for patent protection growing more than fourfold in just five years. This shows that space QT are a rapidly emerging technology segment with a growing number of new inventions.

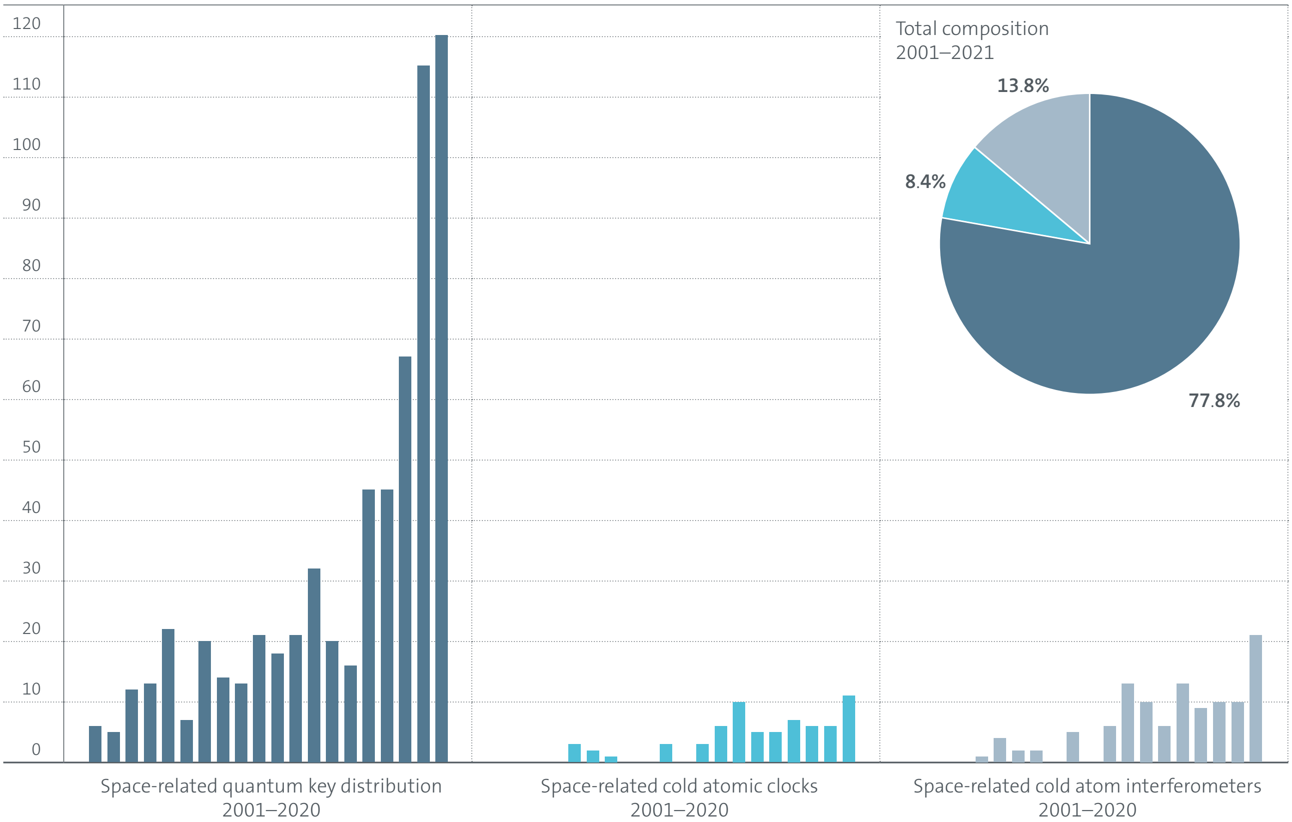
This trend confirms the increasing number of patent filings in both the quantum and space sector that was identified in previous studies.[12] It also shows that the space and quantum sector are gaining in importance both commercially and strategically.

The available patent data also underlines that the application of QT in space is still a niche sector. Even in the specifically selected subdomains, space-related patent filings represent less than 15% of all patent filings (including quantum key distribution, cold atom clocks and cold atom interferometers). When considering all QT patent filings, space-related applications represent an even smaller share as most QT filings concern inventions with limited potential for uptake in the space environment (e.g. quantum computing).

[12] For example: https://www.epo.org/news-events/news/2021/20210721a.html, https://digibug.ugr.es/bitstream/handle/10481/62830/patent_insight_report-quantum_metrology_and_sensing_en.pdf?sequence=1&isAllowed=y or https://publications.jrc.ec.europa.eu/repository/handle/JRC115251

2.2 Key drivers: booming innovation in space-based quantum key distribution

Patent families per QT domain



Earliest publication year

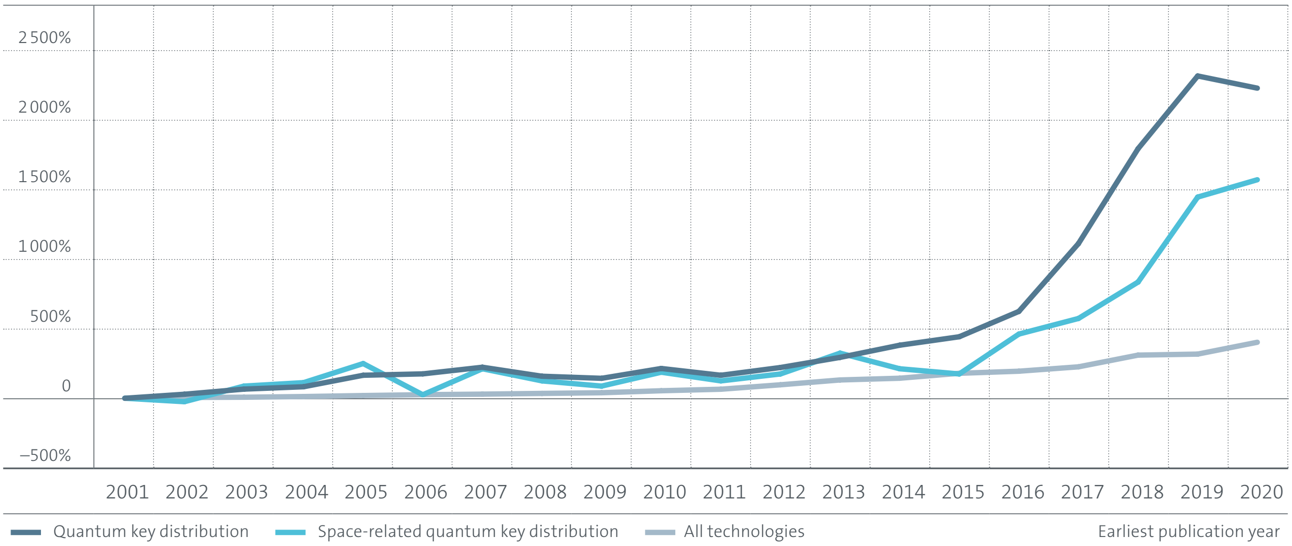
Space-related patent filings in quantum key distribution, cold atom clocks and cold atom interferometers show slightly different trends and huge differences in volume, especially for quantum key distribution.

According to patent data, quantum key distribution is currently the leading application of QT in the space environment, with more than 77% of the identified space-related patent filings relating to quantum key distribution inventions. Ultimately, the overall growth in space-related QT patent filings is largely based on a massive surge in space-related quantum key distribution patents over the last five years.

The prominence of quantum key distribution inventions in the analysed dataset corresponds to broader political and security trends associated with the role of QT in secure communications. In the wake of technological advances in quantum computing, which has the potential to disrupt existing encryption methods for securing communication links, there is a clear sense of urgency to develop new secure communication methods. QT play a prominent role in this regard, with patent data confirming that this urgency is translating into a noticeable wave of new inventions in space-related quantum key distribution. This finding further indicates the important role to be played by satellite quantum key distribution links in secure communication networks and architectures in the future.

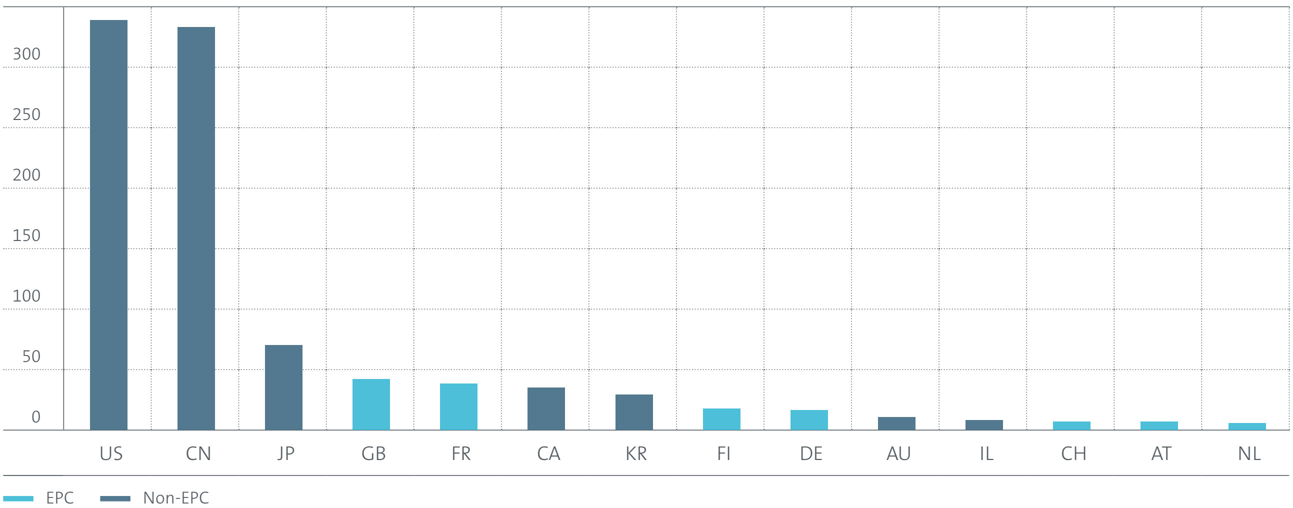
The number of patent families in quantum key distribution grew between 2001 and 2020 by a factor of 20, while the patent filing activity worldwide grew by a factor of 4 during the same period. This can be seen in the following graph, which also shows that space-related quantum key distribution filings specifically grew by a factor of 15.

Growth of patent families compared with 2001



2.3 Inventions originating primarily in the US, China or Japan

Patent families from QT applicant countries (2001–2020)



Most patent applications for space-related QT inventions originate outside Europe, mainly from US, Chinese and Japanese organisations. Within Europe, British, French, Finnish and German stakeholders are most active, followed by Swiss, Austrian and Dutch organisations. Europe's rather minor position in space-related QT is an important finding in view of the strategic importance attributed to QT (and quantum communication in particular) in the EU (the EuroQCI initiative).

Looking at the patent filing data by origin of innovation, it is important to note that different filing strategies by stakeholders from different countries have an impact on the overall statistics. For instance, Chinese applicants choose predominantly domestic filings and do not file for patents on a comparable scale internationally. In addition, Chinese applicants often file utility models[13] as well as patents on the same or similar inventions, and this increases Chinese filing numbers.

[13] "Similar to patents, utility models protect new technical inventions through granting a limited exclusive right to prevent others from commercially exploiting the protected inventions without consents of the right holders. [...] In general, utility models are considered particularly suited for protecting inventions that make small improvements to, and adaptations of, existing products or that have a short commercial life." (https://www.wipo.int/patents/en/topics/utility_models.html)

Country of first applicant	Utility models and patents	Non-domestic filings (ratio)		EP or WO filings (ratio)	
US	290	171	(59%)	158	(54%)
CN	285	20	(7%)	15	(5%)
JP	60	50	(83%)	31	(52%)
GB	36	28	(78%)	20	(56%)
FR	33	27	(82%)	22	(67%)
CA	30	29	(97%)	13	(43%)
KR	25	12	(48%)	6	(24%)
FI	15	15	(100%)	12	(80%)
DE	14	7	(50%)	6	(43%)
AU	9	9	(100%)	5	(56%)
IL	7	7	(100%)	7	(100%)
CH	6	6	(100%)	6	(100%)
AT	6	6	(100%)	6	(100%)
NL	5	5	(100%)	2	(40%)

Analysing international collaboration on the basis of inventors' countries of residence or the locations of head offices shows that EPC countries are heavily involved in cross-country developments and subsequent patent applications, particularly the United Kingdom and France, as can be seen in the table below.

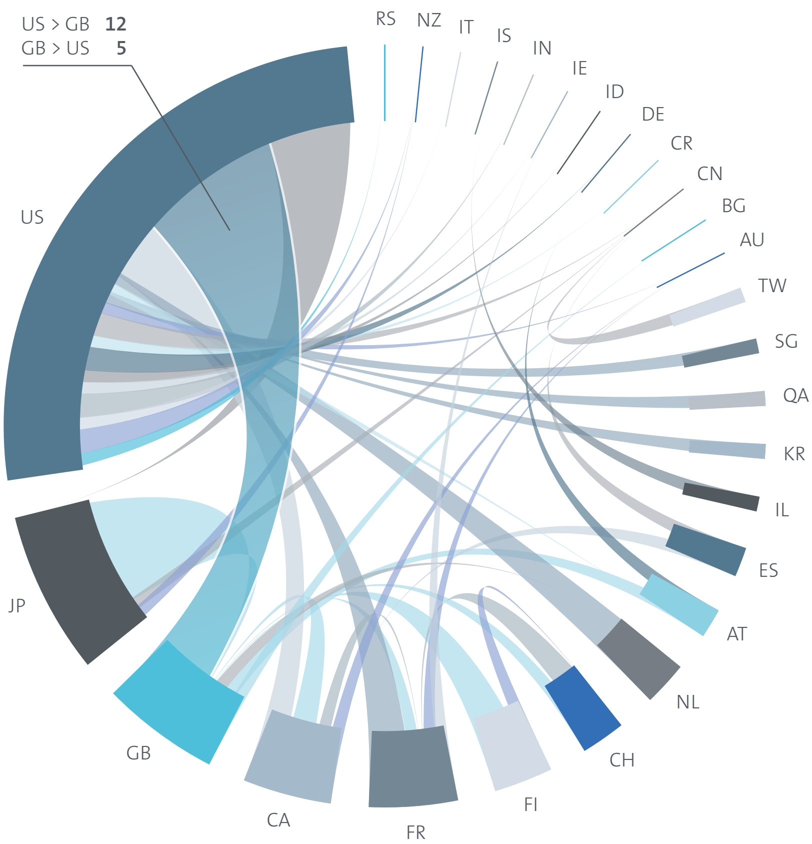
Additionally, further links can be seen when characterising patent families from inventors and applicants residing in different countries. In the figure below, the highlighted example of international co-operation shows 12 US applicants who employ inventors resident in the United Kingdom. Conversely, this is the case for only five GB applicants employing US inventors. All in all, non-EPC country applicants own more inventions involving EPC[14] inventors than vice-versa. Consequently, while a great share of patents in the QT domain originate outside Europe, some European-resident inventors are still involved through international co-operation, i.e. through company subsidiaries.

Patent families with international co-operation[15]

Country collaboration		Families
GB, JP	EPC/non EPC	15
GB, US	EPC/non EPC	15
CA, US	non EPC	7
FR, US	EPC/non EPC	5
CN, US	non EPC	3
FI, GB	EPC	3
GB, JP, US	EPC/non EPC	3
NL, US	EPC/non EPC	3
CA, GB	EPC/non EPC	2
CH, FR	EPC	2
CN, TW	non EPC	2
DE, US	EPC/non EPC	2
GB, JP, NZ, US	EPC/non EPC	2
IN, US	non EPC	2
JP, US	non EPC	2
SG, US	non EPC	2

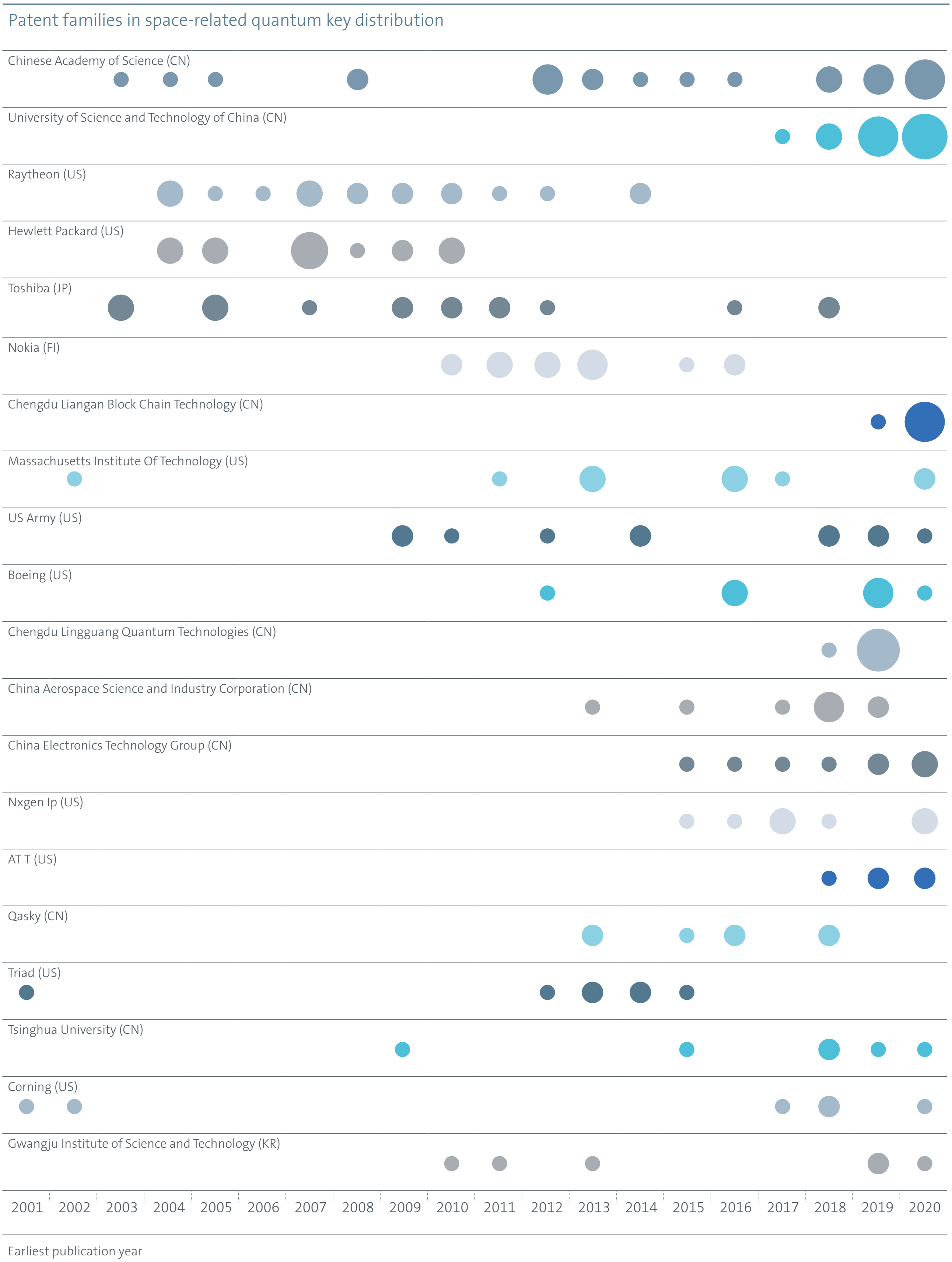
EPC   non EPC   EPC/non EPC

International inventor-applicant collaboration[16]

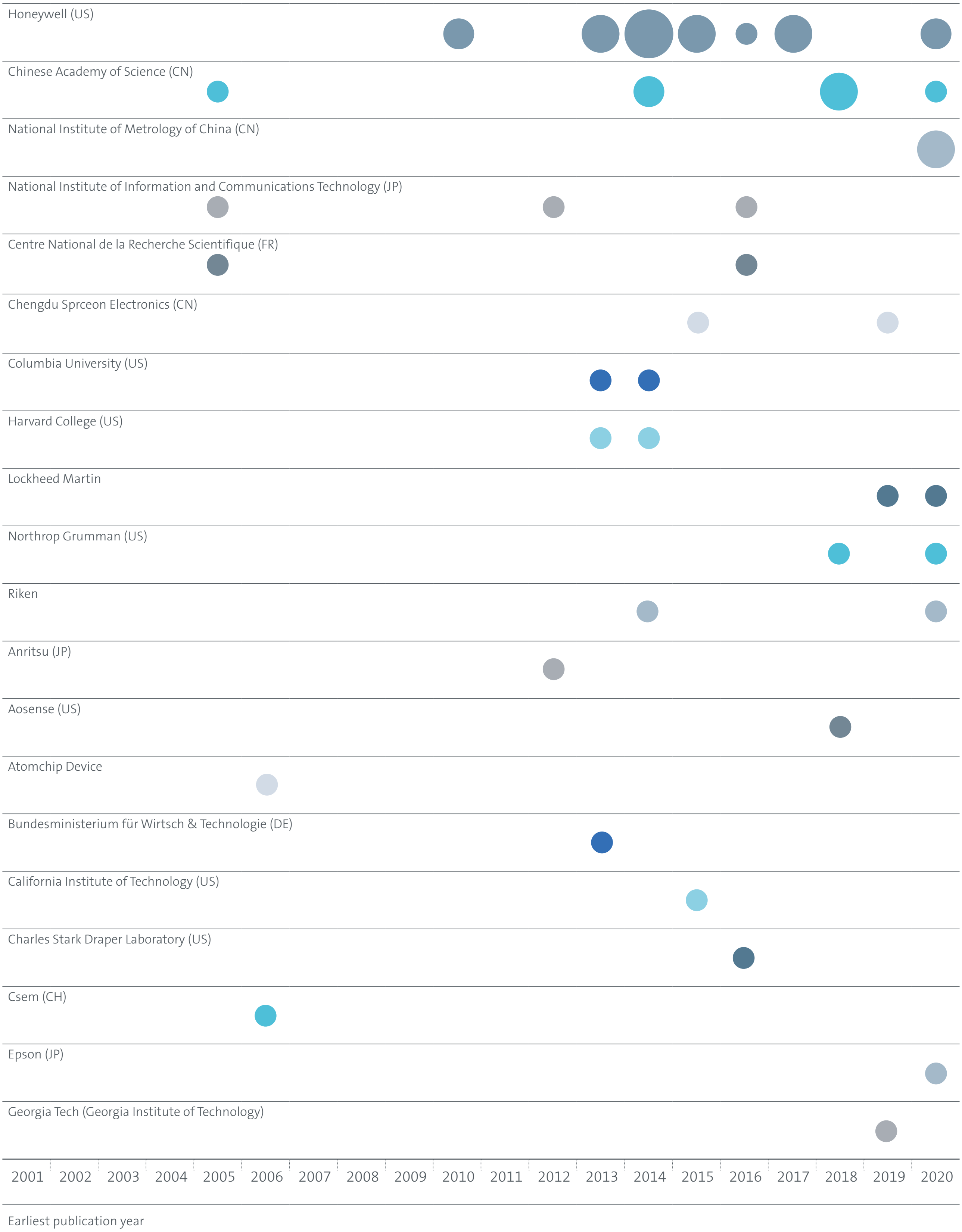


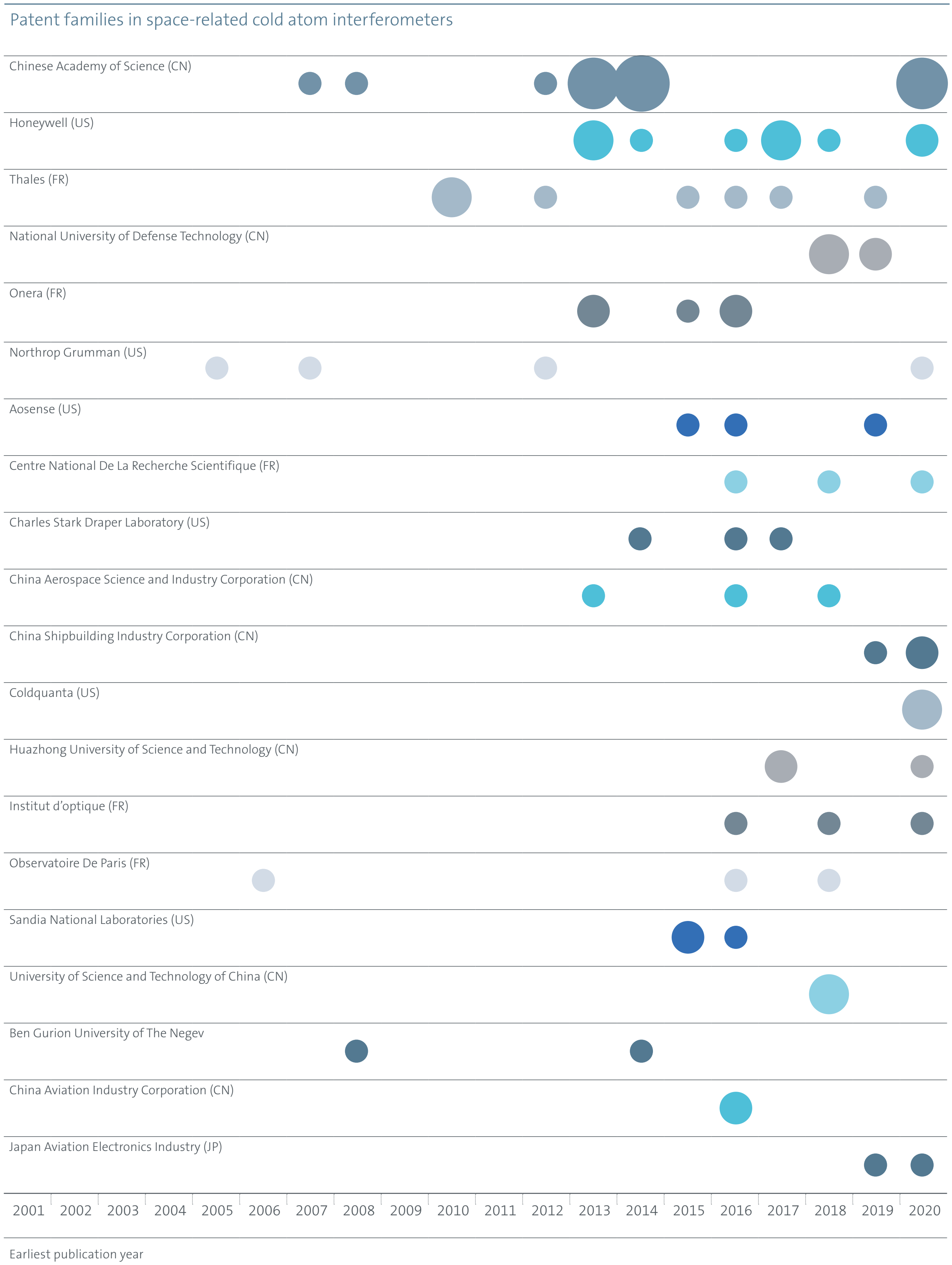
[14] https://www.epo.org/about-us/foundation/member-states.html
[15] Families with inventors or applicants from different countries.
[16] Analysis carried out with PATSTAT Spring 2021 edition.

2.4 Partial overlap between the top players in the three domains of interest



Patent families in space-related cold atom clocks




Patent families in space-related cold atom interferometers
Chinese Academy of Science (CN)
Honeywell (US)
Thales (FR)
National University of Defense Technology (CN)
Onera (FR)
Northrop Grumman (US)
Aosense (US)
Centre National De La Recherche Scientifique (FR)
Charles Stark Draper Laboratory (US)
China Aerospace Science and Industry Corporation (CN)
China Shipbuilding Industry Corporation (CN)
Coldquanta (US)
Huazhong University of Science and Technology (CN)
Institut d'optique (FR)
Observatoire De Paris (FR)
Sandia National Laboratories (US)
University of Science and Technology of China (CN)
Ben Gurion University of The Negev
China Aviation Industry Corporation (CN)
Japan Aviation Electronics Industry (JP)
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Earliest publication year

The patent filing data shows the variety within the investigated QT domains. Apart from a few key names (Chinese Academy of Sciences, China Aerospace Science and Industry Corporation, Northrop Grumman, Honeywell), the charts above overwhelmingly show rather unique lists of the top players active in each domain.

The lists also confirm that, as mentioned above, most space-related QT inventions originate outside Europe.

With regard to organisations from the EPO member states, Thales, ONERA, CNRS, Nokia, Arqit, the University of Oxford and the Austrian Academy of Sciences were identified as major players in terms of patent filings. In addition, patent statistics show that some non-European players have important European subsidiaries producing space-related QT inventions, e.g. Hewlett Packard or Toshiba Research Europe. There are also other players shaping the fields of quantum key distribution, cold atom clocks and cold atom interferometers that either had low patent numbers in the classifications considered, choose not to protect their inventions by patent filings or have been active very recently in 2021 (i.e. Arqit).

While certain names appear to have an ongoing interest in their particular segment, analysing the data over time reveals two specific types of stakeholder:

— organisations that were active in their field in the past but whose filing numbers have dropped (e.g. Hewlett Packard, Raytheon)
— newcomers, i.e. organisations that have entered space-related QT only recently (particularly relevant for China – see the University of Science and Technology of China, Chengdu Liangan Block Chain Technology and Chengdu Lingguang Quantum Technologies)

Trends in terms of technologies based on quantum key distribution and key players are also covered in other similar publications.[17 18]

2.5 Technical challenges preventing greater uptake of QT in the space environment

Most advanced QT still have to overcome significant challenges in order to reach their full potential in space. The challenges may differ in each domain, but one overarching theme is enabling the deployment of QT components in the space environment over their full lifetime. This includes optimisation of volume, energy consumption and weight through innovative design, radiation-hardened components for QT payloads and the precise alignment of optics (and components in general) capable of withstanding launch stresses. There are some promising solutions on the horizon but the success of these will depend on how they are integrated into complete autonomous operational systems.

To benefit from these ultra-precise technologies that have the potential to revolutionise secure communication and metrology and sensing, further inventor ingenuity and policy support are needed.

Despite the overarching challenges, further potential in space-related quantum key distribution is seen in the following:[18]

— highly accurate optical links, owing to the reduction of faint beams and high Earth orbits
— the ability to conduct multiple quantum key distribution protocols
— improved secure key rates and uplink transmission
— greater cost-efficiency
— small and affordable moving receiver platforms
— free-space daylight quantum key distribution
— feasible quantum memories for a global quantum network including non-trusted nodes and full end-to-end encryption

Some of the emerging solutions include superconducting nanowire single-photon detectors (SNSPD) for improved detection, single-pair entangled photons, integrated photonic sources and detectors,[19] and quantum memories with a sufficiently long coherence time.

17 Travagnin, M. and Lewis, A., Quantum Key Distribution in-field implementations, EUR 29865 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-11444-4, doi:10.2760/38407, JRC118150. https://publications.jrc.ec.europa.eu/repository/handle/JRC118150

18 Olivia Lee, Tom Vergoossen, An updated analysis of satellite quantum-key distribution missions. https://arxiv.org/ftp/arxiv/papers/1909/1909.13061.pdf

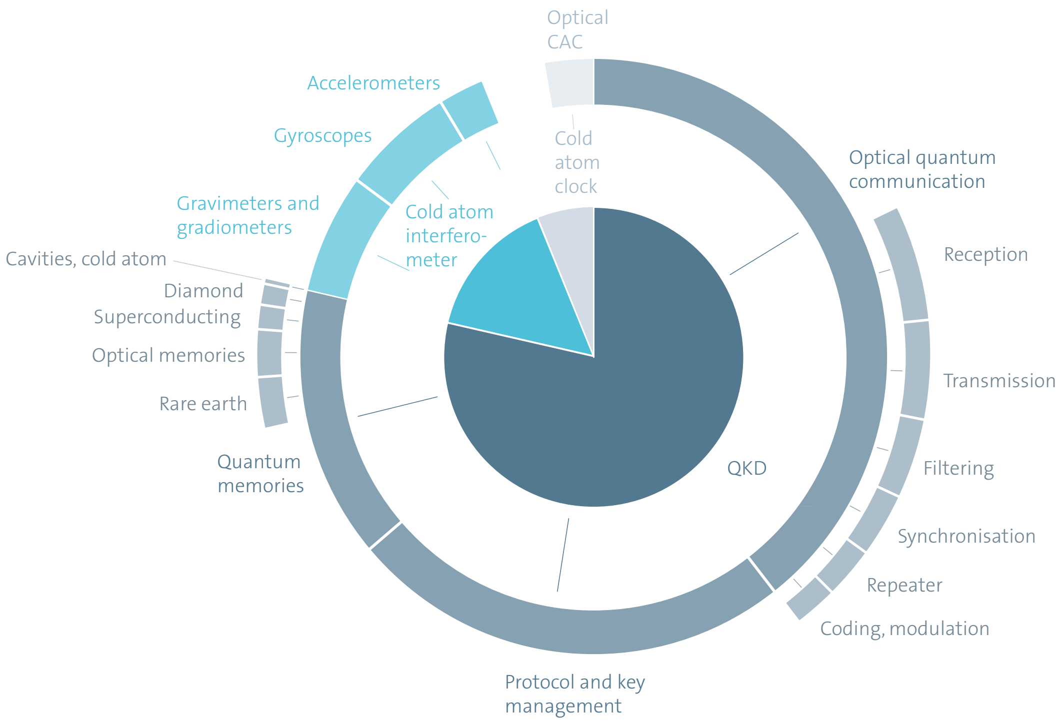
19 https://www.nature.com/articles/ncomms13984

Some of the future challenges identified for cold atom clocks and cold atom interferometers include:

- creating autonomous systems (without any need for human intervention)
- developing standard, non-outgassing interfaces
- minimising or optimising Size, Weight and Power (SWaP), especially with respect to:
  - laser systems
  - ultra-high vacuum generation and maintenance during deployment lifetime
  - magnetic shielding (e.g. for Rubidium-based cold atom interferometers)

Existing and emerging solutions include some models that have been launched into space.[20] Further information on the technology and the challenges is provided in the supplementary material to this publication.[21]

Space-related QT (2001-2020)



2.6 Complementary information per domain

Consolidating the study dataset, the three assessed technology domains were broken down further into several distinct subdomains and groups:

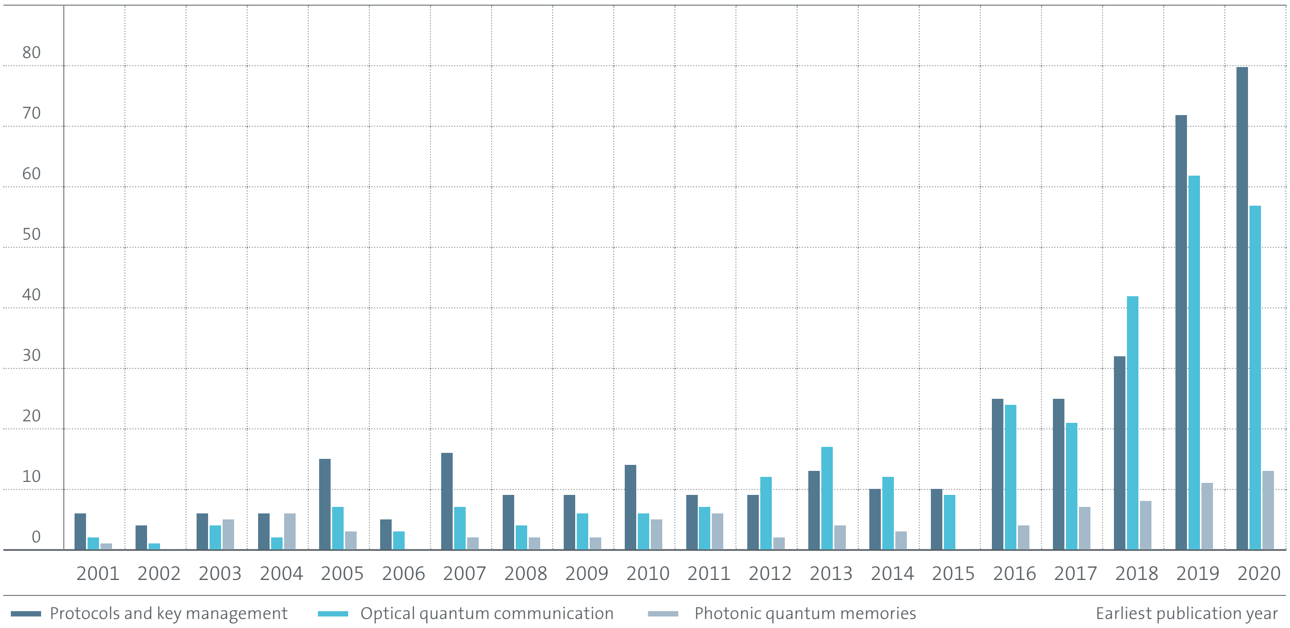
To provide more detailed information, the following figures concern the following two specific patent filing statistics indicators individually for each domain:

1. the change over time of patent filings in the given domain at subdomain level
2. the technology domain "collaboration map" to reveal co-operation trends between different players (who co-operates with whom, any industry-academia partnerships, etc.)

[20] For example, https://academic.oup.com/nsr/article/7/12/1828/5899773
[21] https://www.epo.org/searching-for-patents/business/patent-insight-reports.html

2.6.1 Quantum key distribution

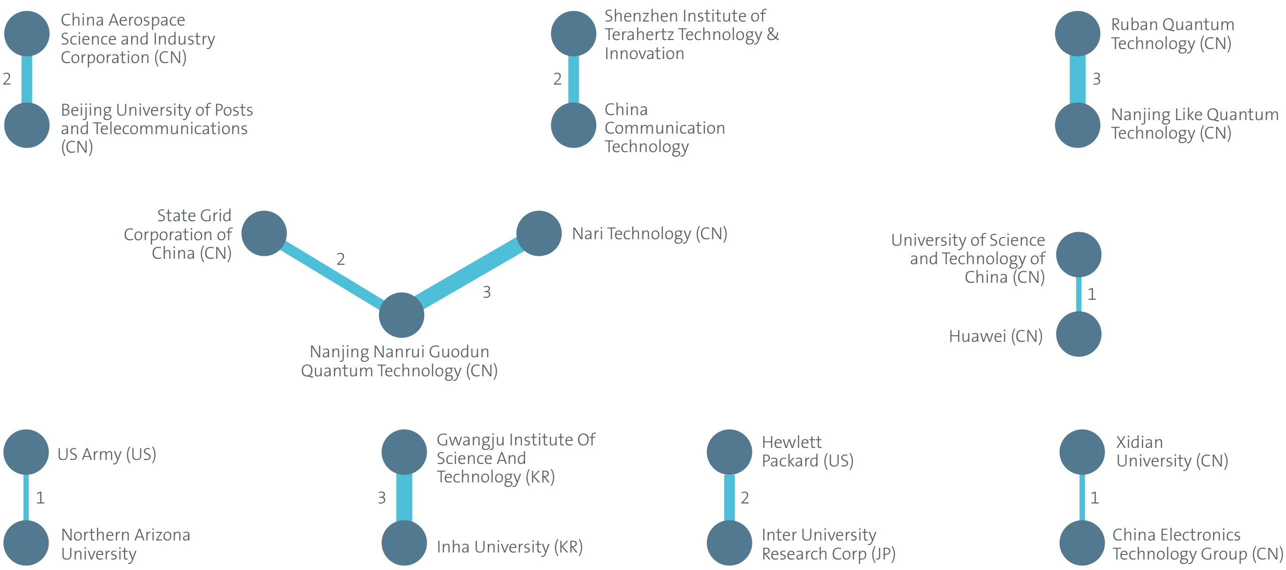
Trends in space-related quantum key distribution patent families



The change over time in space-related quantum key distribution filings shows a significant increase in protocols and key management, as well as in optical aspects of quantum communications. The use of photonic quantum memories seems to face additional challenges preventing a strong surge in space applications. Further details on photonic quantum memories are available in the supplementary material to this report.

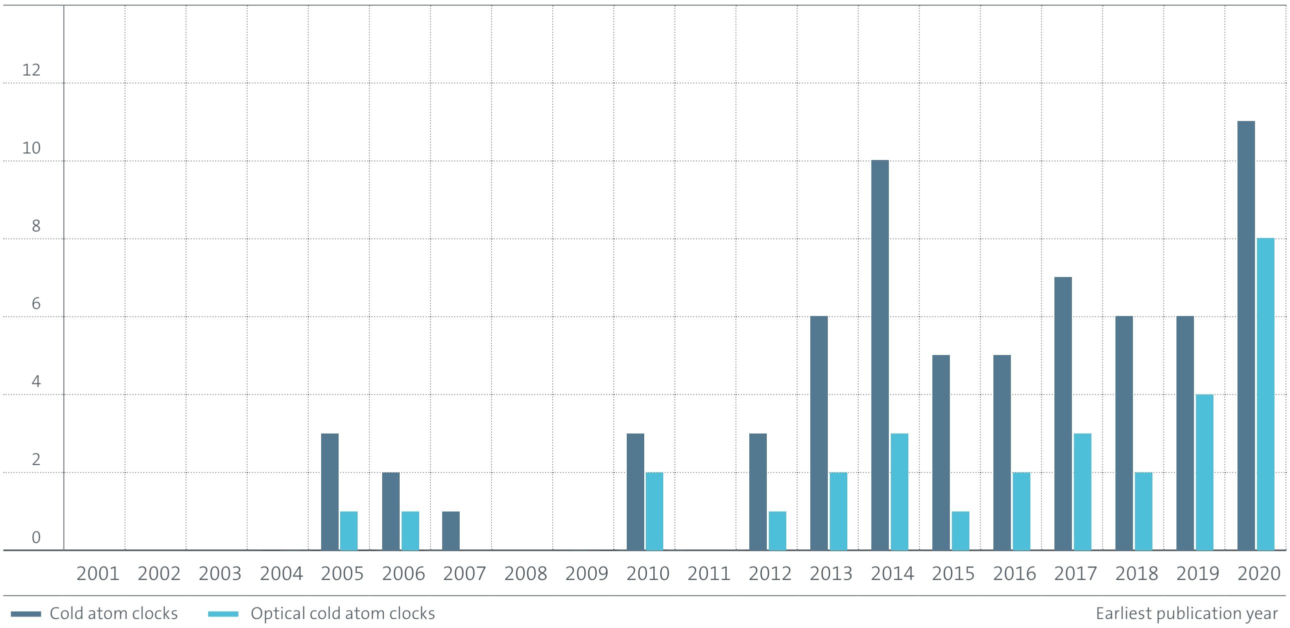
The collaboration map for the quantum key distribution domain shows a number of very small collaboration networks, mostly executed with the direct partnership of two parties. The collaborations also tend to stay at national level.

Collaboration map



2.6.2 Cold atom clocks

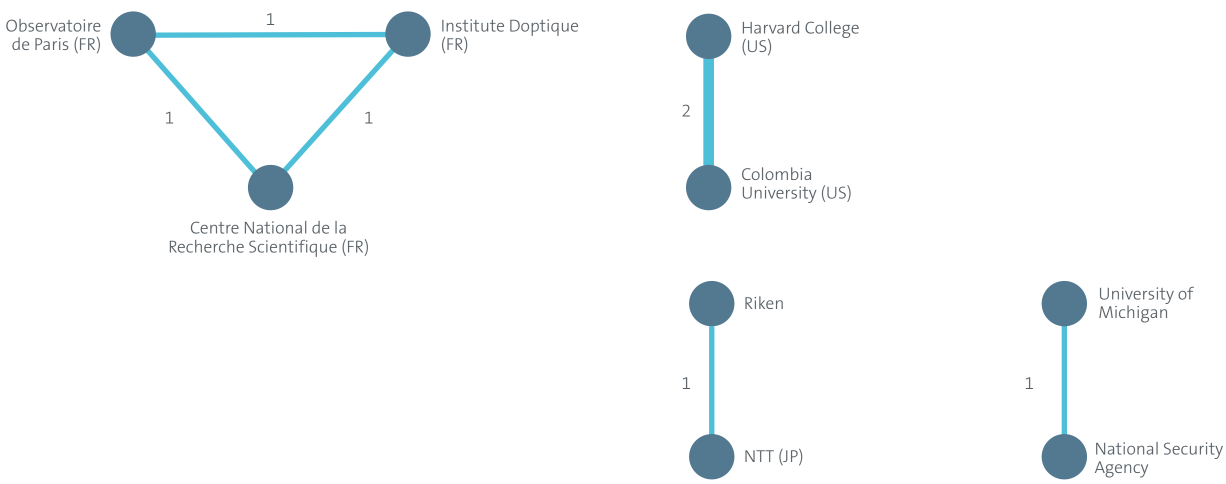
Trends in space-related cold atom clock patent families



The change over time in space-related cold atom clock filings shows the growing prominence of optical cold atom clocks, which have the potential to provide even more accurate measurements (in these, a resonance frequency in the optical domain is used instead of a microwave field).

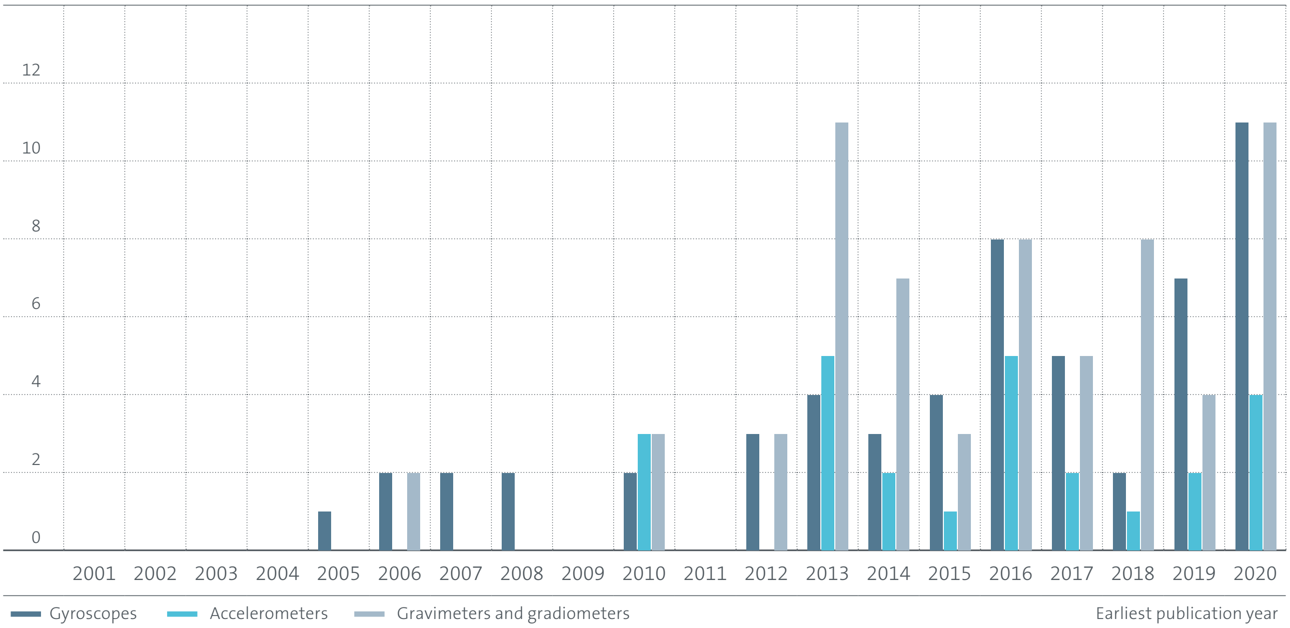
Compared with quantum key distribution, the collaboration map for cold atom clock patents is much smaller, with collaboration in this domain being solely between academia and governments.

Collaboration map



2.6.3 Cold atom interferometers

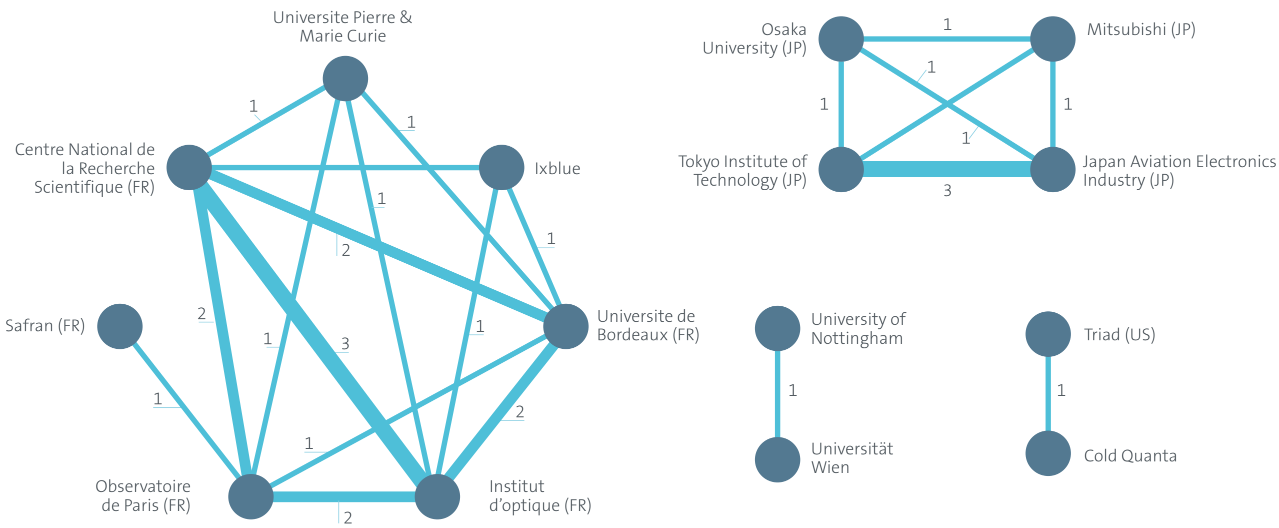
Trends in space-related cold atom interferometer patent families



The change over time in space-related cold atom interferometer filings provides insights into trends in patent filings related to gyroscopes, accelerometers and gravimeters.

The collaboration map for cold atom interferometers shows a strong French cluster with interlinked parties from government, academia and industry, highlighting multi-level co-operation. Another cluster can be seen in Japan, characterised by partnership between academia and industry.

Collaboration map



3. Conclusion

The importance of QT and their specific space applications in today's world is growing rapidly, as evidenced by major government programmes, increasing private investment and entrepreneurship in the field, and patent filing statistics, which have been analysed in-depth in this report.

The great momentum observed in this area will likely spur future innovation and continue to foster the upward trend in patent filings. The analysis revealed that the growth rate in patent filings for space-related QT in the period 2001 - 2020 by far surpasses – by a factor of five – the overall global growth rate in patent filings for all technologies.

Although space-related QT are still a niche segment of the overall domain, some applications, in particular quantum key distribution technologies, are poised to become much larger in the future. This is thanks particularly to their widely recognised strategic value for key challenges such as secure communications and cybersecurity. Today there is a real sense of urgency to devise new encryption methods for telecommunications.

The EU has named the quantum sector as one of its strategic priorities, mentioning specifically the role to be played by space quantum. A key component of this will be a satellite element of the upcoming EuroQCI. While QT are high on European policy agenda, the analysis of patent filing statistics shows that most space-related QT innovations originate outside Europe, with the US and China the frontrunners.

Note on the limits of the study

This study provides a specific snapshot of a particular technology segment. The approach used could serve as an example of how to exploit patent filing statistics for analyses to deliver insights and information to assist decision-making, in both the private and public sectors.

This study makes best use of the EPO's publicly available data, search and other analysis tools. Like many patent analyses, it is based on search queries combining key words and patent classification codes. These queries are designed to optimise recall (i.e. to retrieve as many relevant documents as possible) and to optimise precision (i.e. to exclude as many non-relevant documents as possible). In reality, for a large dataset it is impossible to obtain 100% recall and 100% precision simultaneously. This affects which documents we found, as did the need to use a number of disparate classification codes in the search. For this report we limited our data sample to the earliest publication year of 2001 up to 2020 to recover all relevant QT technologies. We then manually checked a considerable number of patent families to improve precision and recall. However, as a result of the above parameters, "noise" in the dataset is inevitable and some relevant documents may have been missed. Nevertheless, we are confident in our methodology and assumptions.

Glossary

Applicant	A person (i.e. natural person) or an organisation (i.e. legal entity, company) that has filed a patent application. There may be more than one applicant per application.
Espacenet	Free service from the EPO for searching patents and patent applications. Includes more than 130 million documents.
GPI	Global Patent Index (GPI) is a powerful tool that enables users to perform detailed searches in the EPO's worldwide bibliographic, legal event and full-text datasets.
Invention	Practical embodiment which involves, requires or produces a technical effect.
Inventor	A person designated as an inventor in a patent application. An inventor can also be an applicant. An inventor is always a natural person. There may be more than one inventor per application.
Jurisdiction	A country or countries (territory) for which a patent may be granted by the corresponding intellectual property office.
Patent application	Document summarising, describing and defining the scope of an invention for which patent protection is sought.
Patent family	A set of patents covering the same invention but filed at different patent offices. Counting patent families is a good proxy for counting inventions and removes possible bias introduced by the geographical coverage of the envisaged protection for the invention leading to an increased number of publications. The family size refers to the patents included in a patent family.
PATSTAT	The EPO's PATSTAT database has become a point of reference in the field of patent intelligence and statistics. It helps users perform sophisticated statistical analyses of bibliographical and legal event patent data.
Priority filing	The first-filed patent application of a family. The priority year/date is the year/date in which a first filing is filed.

List of major public QT initiatives

2014	The UK starts the first phase of the National Quantum Technologies Programme (2014-2019) with a total budget of £270 million.
2016	Austria launches the national R&D funding programme for quantum research and technology with a budget of €32.7 million over 2017-2021.
2017	Sweden launches the Wallenberg Centre for Quantum Technology, an approximately €100 million quantum computing research initiative. China[22] announces it is investing $10 billion in the world's largest quantum research facility – the National Laboratory for Quantum Information Sciences. In Australia, the Australian Research Council invests around €100 million over seven years in its four quantum-focused Centres of Excellence.
2018	Germany launches the multi-annual framework programme on QT, providing funds of approximately €650 million between 2018 and 2022. The European Commission launches the Quantum Technologies Flagship with an expected budget of €1 billion from the EU over ten years. The USA launches the National Quantum Initiative, with a five-year budget of over $1.2 billion. Japan launches the Q-LEAP (Quantum Leap) initiative with an envisioned ten-year budget of $200 million.5 Singapore invests $90 million in the Quantum Engineering Programme, from 2018 to 2025. Hungary initiates the National Quantum Technology Programme with a government subsidy of €11 million over a four-year period.
2019	Russia announces a $663 million investment over the next five years in basic and applied quantum research carried out at leading Russian laboratories. Israel introduces an approximately $300 million national initiative on quantum computing. The UK launches the second phase of the National Quantum Technologies Programme, with combined investment hitting a £1 billion funding milestone. South Korea starts a five-year Development Program for Quantum Computing, investing around $40 million.
2020	Taiwan announces it will invest $282 million in the development of QT in the coming five years. India introduces the National Mission on Quantum Technology with a budget of approximately $1 billion over a five-year period. Germany announces a new €2 billion innovation programme for QT.
2021	France announces a five-year investment plan in QT worth €1.8 billion. The Netherlands unveils Quantum Delta NL, a public-private QT partnership. The investment includes €615 million over seven years and can count on up to €3 billion in private co-investment. Canada allocates $290 million over seven years for its first National Quantum Strategy.6

Note: the list above primarily considers national initiatives and large-scale QT-related programmes. Recently there has also been notable public support for QT (in other forms such as smaller initiatives, centres of excellence, government subsidies and industry partnerships) in Denmark, Iran, Italy, Norway, Switzerland, Taiwan, Thailand and the UAE. Available reports suggest that large-scale public initiatives and investments in QT research have yet to get going on a large scale in Latin America or Africa. In this regard, in late 2020 BRICS countries launched a major quantum communication research partnership, providing Brazil and South Africa with new opportunities to join the quantum race.

[22] It is estimated that China had already invested several billions ($) in QT prior to this announcement.

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Authors
Johannes Schaaf (EPO)
Tomas Hrozensky (ESPI)
Sebastien Moranta (ESPI)
Stephan Speidel (ESA)

Examiners
Andreas Gröger (EPO)
Habib Mérimèche (EPO)
Celine Borsier (EPO)
Thierry Bec (EPO)

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Björn Jürgens (University of Granada)
Geert Boedt (EPO)
Sonia Kaufmann (EPO)
Nuria Hernández Alfageme (ESA)

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