PREPARED BY

IAC CAI | QUANTUM ALGORITHMS INSTITUTE

Quantum Technologies 2026

IP and Market Intelligence

April 2026

Foreword

The science of quantum mechanics has been around for a century but we have only really begun to engineer quantum products and services in the last 25 years.

Quantum is not just another high tech opportunity: it is a transformative technology that will provide massive improvements across all aspects of today's economies: business, health, public service, climate change and defence. However, it will also disrupt and challenge work, pricing models, value creation, military and intelligence activities and cybersecurity practices.

Tracking and understanding what is going on in the quantum sector - in science, technology, and business - is a gargantuan task. The technology is complex. Quantum offers transformative solutions across a huge range of activities. Rapid change and advances are being driven by unprecedented levels of public and private investment. Few people fully understand the technologies that are being developed and a different, but equally small group of experts have a clear view of what is happening in the burgeoning commercial market for quantum.

The international patent landscape for quantum reflects all these factors. Some multinational companies, such as IBM, have been working on quantum computing since the nineties and have long-established patent portfolios. Significant innovation in quantum has been pioneered by academics and by start-up companies since the turn of the century - creating the long tail of patent families referred to in this report. Government and commercial interest in quantum solutions has rapidly accelerated the creation of quantum companies and the number of patents filed and awarded in the last decade.

Interest in quantum as a commercial and sovereign opportunity has been driving large and multinational companies to strengthen their quantum patent portfolios as a strategy in value creation and opportunity management.

In a field as competitive as quantum, the importance of an appropriate IP strategy - including patents, trade secrets, know-how and selecting the right protections at the right time, is very important. In Canada, companies such as D-Wave, Xanadu, 1QBit and Photonic have well-established IP strategies. For academics, researchers and startup companies, suitable IP protection must be established early to lock in future value. Today's companies can benefit from expertise, advice and resources that organizations including ISED, IAC, New Ventures BC, IPON, Elevate IP partners, universities and business incubators have to offer - increasing the opportunity to protect and retain value for entrepreneurs, businesses and the Canadian economy.

The appeal of quantum as a concept - and simply as a word - has led many entrepreneurs to attach the label quantum to their patent applications, even when the product or service being offered is not related to any element of quantum mechanics. Quantum soap and quantum massage oil have readily been removed from the data used by the IAC team to compile this report. But distinguishing between real quantum solutions and quantum as marketing is much more subtle and difficult for highly technical quantum patent applications. IAC's patent experts have worked diligently to provide a dataset and subsequent analysis that are as reliable as possible.

Capturing an accurate picture of the quantum technologies and business solutions offered by large and small companies in Canada and around the world offers its own challenges - particularly in such a fast-moving and wide-ranging set of markets. QAI and IAC have worked together to provide a market overview that is as complete and reliable as possible.

As the quantum sector continues to advance, this thorough and business-oriented analysis of the world of quantum patents creates an important and informative foundation to anchor our understanding of the growing market for quantum products and services.

LOUISE TURNER
CEO, Quantum Algorithms Institute

IAC · CAI

IAC was born out of the Federal IP Strategy established in 2018 to enhance the ability for small to medium-sized enterprises (SMEs) in cleantech to utilize the IP in global markets.

IAC was chosen to administer the $30M Patent Collective Pilot Project. The goal was to increase SMEs freedom to operate and implement effective IP strategies. IAC was launched in December 2020 and operates as a membership-based not-for-profit organization.

QUANTUM ALGORITHMS INSTITUTE

The Quantum Algorithms Institute (QAI) is a non-profit organization advancing quantum solutions through collaboration with government, academia, and industry. Its mission is to drive economic growth in British Columbia by fostering quantum literacy, preparing a skilled workforce, and helping organizations adopt quantum technologies. Founded in 2020, QAI builds on BC's strengths to create a thriving quantum economy and position the province as a leader in innovation.

Table of Contents

Table of Contents

1

Introduction

The global quantum technology landscape is undergoing a profound transformation - driven by scientific breakthroughs, strategic national investments, and accelerating commercial readiness. IAC's Quantum Technologies IP Intelligence Report examines this ecosystem through the lens of intellectual property, offering a deep, data-driven view into the evolving innovation landscape across **Quantum Computing, Communications, Sensing, Applications, and Materials.**

This comprehensive study brings together two core pillars of analysis: **patent intelligence** and **market research** to present a clear picture of where the field stands today and where it's headed. This report delivers data-driven insights grounded in rigorous patent and market analysis. It is designed to provide actionable intelligence for industry stakeholders, investors, and policymakers, combining depth, clarity, and evidence-based perspectives to support strategic decision-making in this space.

1

Introduction

What's Inside?

- **Patent Analysis:** Using a structured taxonomy, we examined over **83,091** patent families related to Quantum Technologies. This section highlights innovation hotspots, key players, and emerging technology domains.
- **Value Chain Exploration:** A dedicated section maps the full Quantum Technologies value chain from raw materials to components, devices, communications, software, and cloud-based solutions. This provides visibility into industry activities across sectors and uncovers potential collaboration opportunities.
- **Market Dynamics & Policies:** We mapped the competitive landscape, highlighting major players, emerging trends, and regional policies driving adoption and development. This offers a clear understanding of the current market dynamics and future growth potential.

1

Introduction

What additional data is available?

This report draws from a comprehensive dataset of **83,091 patent families** that enabled deep, data-driven analysis across technologies and market segments. While the report presents key findings and selected visuals, a wealth of additional graphs, breakdowns, and insights were generated during our research. To maintain clarity and focus, not all of this supplementary analysis is included in the final publication.

IAC members have access to the complete dataset that enables custom exploration and deeper dives into specific technologies, companies, and trends. IAC's team also brings the expertise to support tailored analysis based on your strategic needs.

For access to the data or to request custom insights, please contact ipintelligence@ipcollective.ca.

2

FAQs for Quantum Technologies Report

If you require further insights, our team is ready to assist you. As a valued IAC member, you have access to:

- Personalized guidance from our IP Intelligence team to help you with your patent searches and landscape analyses.
- Exclusive access to patent search and landscape courses through the IAC's Education Hub, tailored to assist you in your IP journey.

Contact us to unlock the full potential of your IAC membership.

- What are the key sections to quickly navigate if time is limited?
- Who are the key players within the Quantum Technologies value chain?
- Which technologies were considered for this study?
- What is the global and Canadian patenting scenario?
- Which countries have the most number of granted patents?
- Which companies have the most filings globally? What are their areas of focus?
- Which companies have the most filings in Canada?
- Which Canadian companies have a presence in the patent landscape?
- What are some of the policies and initiatives shaping the Canadian ecosystem?

TABLE OF CONTENTS

3

Key Takeaways

3.1 Key Takeaways

Quantum technologies are transitioning from research-driven experimentation to early commercial deployment, marking a pivotal shift between 2020 and 2025. Encompassing quantum computing, communications, and sensing, the global quantum market reached approximately **US$1.45 billion in 2024**, with strong growth expected as governments and large enterprises increasingly treat quantum as strategic infrastructure alongside AI and advanced semiconductors. While large-scale economic impact remains longer term, momentum is building across pilots, cloud-based access models, and mission-critical applications.

Market Outlook and Drivers

Market growth is driven by three reinforcing forces. First, **technology maturation** is accelerating, with leading firms advancing hardware roadmaps toward fault-tolerant systems in the early-to-mid 2030s, supported by breakthroughs in error correction, control engineering, and hardware–software co-design. Second, **demand-side pull** is emerging from energy, materials, chemicals, life sciences, finance, and logistics, where quantum-enabled modeling, optimization, and simulation address problems intractable for classical computing. Third, **government investment and national strategies** are shaping market formation: more than 30 countries now maintain formal quantum strategies, linking public funding to economic competitiveness, security, and technological sovereignty.

Deal Making and Commercialization

Commercialization is progressing through **Quantum-as-a-Service**, cloud access, and hybrid classical–quantum workflows. Partnerships between quantum firms and cloud providers, industrial customers, and defence agencies dominate deal activity, while mergers and acquisitions remain selective and strategic. Capital deployment is concentrated among a small group of hardware leaders, software platforms, and sensing specialists, with government-backed programs and consortia playing a critical role in de-risking private investment.

3.1 Key Takeaways

Patent Trends and Competitive Dynamics

Global patent activity underscores the sector's strategic importance. More than **83,000 quantum patent families** have been filed worldwide, with filings growing at approximately **14% CAGR from 2015 to 2022**, a record year. Patent ownership is highly concentrated geographically: **China accounts for ~63% of global filings**, followed by the **United States (~20%)**, with a long tail of countries contributing smaller, specialized portfolios. Quantum computing dominates patent activity, particularly superconducting qubits, while quantum communications, sensing, and materials reflect growing security and near-term deployment priorities.

Risks and Opportunities for SMEs

For SMEs, the opportunity lies less in competing at scale and more in **strategic positioning**. Key risks include long commercialization timelines, high capital intensity, talent shortages, evolving standards, and increasing export controls tied to dual-use concerns. However, significant opportunities exist in **software layers, error correction, benchmarking, sensing applications, quantum-safe security, and domain-specific solutions** integrated into larger platforms. SMEs that align with national programs, leverage public funding, partner with large incumbents, and focus on niche, application-driven capabilities are best positioned to capture value as the quantum ecosystem moves from development to deployment.

3.2 Key Takeaways: Patent Trends

Dominance of China and Gaps for Canada

Data snapshot, 2005-2025

Chinese patent filings overwhelmingly dominate the quantum sector. While major industrial and technology players such as IBM, Google, Samsung, and Northrop Grumman maintain significant patent portfolios, their volumes remain small relative to filings originating from Chinese universities, research institutes, and state-backed enterprises. Patent filings in Canada and those owned by Canadian assignees remain marginal, even when compared with other non-Chinese jurisdictions, highlighting a persistent gap between Canada's research capability and its scale of patent ownership in quantum technologies.

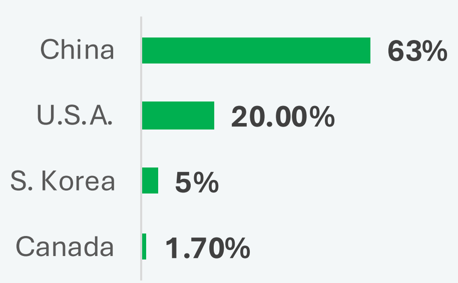
83,091

PATENT FAMILIES

GROWTH

14% CAGR since 2015 to 2022; **2024** was a record year (4,070 families).

Filing Jurisdiction



TECHNOLOGY MIX*

Quantum materials~66%, Fundamental principles~24.5%, Quantum Infrastructure~20%, Quantum Sensing~6%

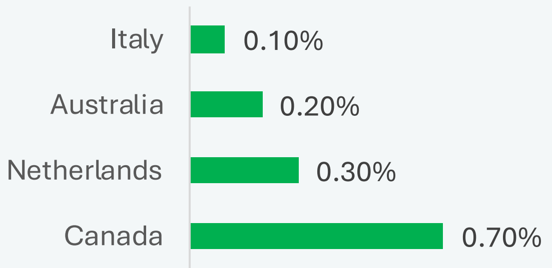
FILINGS IN CANADA

1,422

Patent families

filed domestically, versus **16,648** in USA

Assignee Country



Canadian assignees hold 567 families worldwide (~ 0.7% share).

TOP ASSIGNEES

TCL (2991), Samsung (2065), BOE (1898), Origin Quantum (1327), IBM (862), Jiangxi Zhao Chi Semiconductor (640), Institute of Semiconductors - Chinese Academy of Sciences (639)

***Note:** Where applicable, patents and patent applications have been bucketed into multiple categories. Methodology details can be found here.

3.3 Key Takeaways: Canada

Canada's Strategic Position in Quantum Technologies

Canada's quantum ecosystem is anchored by world-class research, a dense network of commercial startups, and growing government commitment. With the highest number of quantum SMEs per capita globally and a presence at the G7, Canada is positioning itself as a leading quantum nation. As demand for quantum computing, sensing, and communications accelerates, Canada is well placed to shape the next generation of quantum solutions.

TIPS FOR SMES – Focus on specific, high-value quantum sub-domains such as quantum sensing, error correction, or post-quantum cryptography, and partner with established players (Photonic, Xanadu, D-Wave, Nord Quantique) to access platforms, talent networks, and international government programs faster.

Funding and Investment

GLOBAL QUANTUM INVESTMENT

McKinsey Digital forecasts the total market value of quantum companies will reach **US$97 billion by 2035**, enabling US$0.9T–US$2.0T of new value across energy, pharma, finance, and logistics.

CANADIAN QUANTUM CHAMPIONS

Photonic, Xanadu, Nord Quantique and Anyon are backed by the federal Canadian Quantum Champions Program. Three of them are also part of the US DARPA Quantum Benchmarking Initiative.

PUBLIC INVESTMENT PROGRAMS

31 countries plus the EU have collectively committed over **US$60 billion** of public funding into national quantum initiatives, matched by US$11B+ in private equity into quantum companies.

Canada's Quantum Ecosystem

CANADA'S QUANTUM STARTUP ECOSYSTEM

Canada has the **highest number of quantum SMEs per capita globally** and represents 5% of the developed world's commercial quantum workforce despite being only 0.5% of the world's population. BC is the birthplace of commercial quantum computing (D-Wave, 1QBit and Photonic).

CANADA AT THE G7 & INTERNATIONAL STAGE:

In June 2025, Canada introduced Quantum as a new technology at the **G7 Leaders' Summit in Kananaskis**. Quantum is now central to Canada's sovereign and economic growth strategy, including the new Canadian Defence Industrial Strategy.

4

Technology Taxonomy

This section outlines the technology taxonomy developed to categorize patent filings relevant to Quantum Technologies, encompassing both advanced quantum systems and foundational quantum technologies. In addition to emerging quantum computing, communications, sensing, applications, and materials, the taxonomy incorporates established first-generation quantum technologies such as quantum tunneling, atomic clocks, superconducting quantum interference devices (SQUIDs), magnetometers, quantum thermometers, quantum acoustic sensors, quantum dots, and quantum wells.

The taxonomy supports systematic analysis of patent filings and innovation trends across key segments of the quantum landscape and focuses on five core tiers: Quantum Computing, Quantum Communications, Quantum Sensing & Measurement, Quantum Applications, and Quantum Materials.

To establish a consistent classification structure, we analyzed technology whitepapers, seminal patents, product literature, and academic research. This informed the development of a five-level taxonomy enabling granular identification and categorization of patents and published applications across foundational and next-generation quantum technologies, forming the analytical basis for mapping innovation activity across the quantum ecosystem. Read more about the methodology here.

TABLE OF CONTENTS

4.1 Quantum Technologies: Taxonomy with Patent Distribution (Global)

Quantum Technologies

Quantum Computing (41,075)

- Quantum Hardware/ Qubit technologies (5,369)
- Quantum Software (3,084)
- Quantum Control Systems (12,704)
- Fundamental Principles (20,359)
- Quantum Error Correction (2,014)
- Quantum Error Mitigation (58)
- Quantum Infrastructure (16,747)

Quantum Communications (7,799)

- Quantum Cryptography/ Quantum-Safe Encryption (3,198)
- Quantum Networking (3,771)
- Quantum Communication Protocols (404)
- Quantum Communication Hardware (1,380)

Quantum Sensing & Measurement (6,954)

- Quantum Metrology (1,952)
- Quantum Imaging (1,105)
- Quantum Sensing Technologies (4,799)
- Quantum Image Processing (39)

Quantum Applications (64,433)

- Quantum Simulation (481)
- Quantum Optimization (2,120)
- Quantum Machine Learning (964)
- Quantum Cryptographic Applications (7,887)
- Healthcare & Pharmaceuticals (3,599)
- Finance (292)
- Logistics & Supply Chain (128)
- Energy (7,099)
- Artificial Intelligence (7,218)
- Chemistry & Material Science (28,757)
- Communications (25,139)
- Defence (90)
- Transportation (2,028)
- Display & Lighting (18,696
- Environment (1,507)
- Manufacturing (126)

Quantum Materials (54,600)

- Quantum Dots (41,292)
- Quantum Well (13,272)
- Topological Insulators (2,704)
- Superconductors (709)
- Complex Magnets (186)
- Graphene (5,187)
- Ultra-cold Atoms (100)
- Multiferroics (24)

Note: Where applicable, patents and patent applications have been classified into multiple technology categories. Each category is further divided into detailed sub-categories, which are outlined in Appendix B, while descriptions of individual technology tags are provided in Appendix C. Methodology details are described here. Additional information regarding patent filings across diverse sub-categories is accessible to IAC Members. Additionally, IAC Members receive exclusive access to a patent tool for in-depth analysis of the data. Please Contact us for inquiries and to set up your access.

5

Quantum Technologies: Value Chain

5.1 Quantum Technologies Value Chain

Introduction & Purpose

A **value chain** represents the series of **value-adding business activities and processes** involved in delivering a product or service to the market. Each segment of the chain contributes distinct capabilities, from component manufacturing to data analytics - that collectively form the foundation of the Quantum Technologies ecosystem.

IAC's landscape studies apply a sector-level value chain framework to systematically organize patent and market trends, and to analyze **competitive positioning** within the industry. Examining these value chains allows for the extraction of **meaningful insights** about where companies operate, who sits upstream or downstream, and what potential **opportunities or risks** may exist within the evolving ecosystem. The **Quantum Technologies value chain** developed for this study encompasses seven primary functional segments: **Raw/Processed Materials, Quantum Components, Quantum Sensors, Quantum Computers, Quantum Communications, Quantum Software** and finally **Quantum Computing-as-a-service**.

Note: This is not an exhaustive list of companies Only companies with publicly available information and relevance to the study have been included. Companies may appear in multiple categories if they operate across different segments of the value chain

How to Read and Use This Value Chain

Companies can use this value chain to **identify their current market position**, understand potential **integration or partnership opportunities**, and **pinpoint emerging technology or investment gaps**. By mapping themselves against competitors, businesses can better align strategic priorities and innovation efforts across the sector.

Next steps: Organizations are encouraged to (1) assess where their capabilities fit within the value chain to inform growth or collaboration strategies, and (2) monitor shifts across adjacent segments to anticipate technological or market convergence trends. Companies that believe they belong in this value chain and are not yet represented are invited to reach out to the IAC team at ipintelligence@ipcollective.ca to be considered for inclusion in future updates.

5.2 Value Chain: Description

Raw/Processed Materials

Includes fundamental materials required for quantum technology, including superconductors, photonics, and cryogenics.

The market is projected to grow from **USD 13.77 B** in 2025 to **USD 55.9 B** by 2030, at a CAGR of **32.34%** over the period. (Source)

Quantum Components

Includes specialized physical and optical hardware systems that enable the operation, stability, and precision required for quantum technologies.

The market is projected to grow from **USD 365 M** in 2025 to **USD 480 M** in 2030 at a CAGR of **5.6%** over the period. (Source)

Quantum Devices: Sensors

Includes quantum sensors that use quantum phenomena to achieve highly sensitive measurements.

The market is projected to grow from **USD 381.5 M** in 2025 to **USD 850 M** in 2030 at a CAGR of **14.3%** over the period. (Source)

Quantum Devices: Computers

Includes hardware and infrastructure for quantum computing, encompassing various qubit technologies, supporting electronics, and control systems.

The market is projected to grow from **USD 1.53 B** in 2025 to **USD 6.82 B** in 2030 at a CAGR of **34.8 %** over the period. (Source)

Quantum Devices: Communications

Includes **technologies enabling secure communication and information transfer using quantum mechanics**, ensuring unbreakable encryption and ultra-secure networks. It includes **hardware, protocols, and supporting infrastructure** for quantum-secured communications

The market is projected to grow from **USD 1.45 B** in 2025 to **USD 5.39 B** in 2030 at a CAGR of **31.8%** over the period. (Source)

Quantum Software

Includes software development for quantum computing, including quantum AI and error correction.

The market is projected to grow from **USD 1.07 B** in 2025 to **USD 2.51 B** in 2030 at a CAGR of **18.5 %** over the period. (Source)

Quantum Computing-as-a-Service

Includes Quantum Computing as a Service (QCaaS), Cloud-based quantum simulators, Hybrid HPC integration, Secure VPN & telecom network integration for quantum services.

The market is projected to grow from **USD 3.54 B** in 2025 to **USD 14.18 B** in 2030 at a CAGR of **30.1 %** over the period. (Source)

Workforce & Education Programs

Includes Quantum education platforms, Workforce training programs, university partnerships

Research & Development

Includes fundamental research, prototype development, industry-academic collaborations

Governance & Financial Framework

Includes government policies, regulatory frameworks, subsidies and investments

Quantum Applications

Includes practical deployment of quantum computing in various industries such as finance, pharma, and defence.

5.3 Value Chain: Quantum Materials, Components & Sensors

TABLE OF CONTENTS

GLOBAL

Raw/Processed Materials

- American Elements – The Materials Science Manufacturer®
- elementsix – De Beers Group
- genmat
- Linde
- Munich Quantum Instruments
- Nanosys
- Oxford Instruments
- quantum technology supersensors
- Samsung

Quantum Components

- AQT
- Bluefors
- C12
- ChinaProsp Quantum
- IDQ
- IONQ
- Leonardo
- Microsoft
- Munich Quantum Instruments
- Nanosys
- NEXT
- NuCrypt
- NVIDIA
- Oxford Instruments
- OQC
- Pixel Photonics
- Photonscore.
- Photon Queue
- PsiQuantum
- Quanfluence
- QCi – Quantum Computing Inc
- Quantum Opus
- Quantum Machines
- Qphox
- Raicol Crystals – An Oxide company
- Scalinq
- Silent Waves
- Single Quantum – Excellence in photon detection
- Sparrow Quantum
- Turinga
- zero point motion
- Zurich Instruments

Quantum Sensors

- adamantQ
- Advanced Quantum
- AOSense
- Atomionics
- Cybrane
- diatope
- IBM
- IDQ
- Infleqtion
- IONQ
- Miraex
- Qnami
- Quans
- Nomad Atomics
- Phasor Innovation
- QuaNVia
- Quantum Catalyzer
- Quantum Diamonds – Sensor Technology
- quantum technology supersensors
- Rydberg
- Sungkyunkwan University
- Sweden Quantum
- Zabre
- zero point motion

CANADA

Raw/Processed Materials

- Applied Quantum Materials Inc.
- RSL

Quantum Components

- Aeponyx
- Dream Photonics
- Ki3 Photonics Technologies
- Q-Block Computing
- UQDevices
- Zero Point Cryogenics

Quantum Sensors

- Applied Quantum Materials Inc.
- HighQ Technologies
- Ki3 Photonics Technologies
- Norcada
- OSCP
- Phantom Photonics
- QuantaSense
- Qubic
- SBQuantum
- to.technology

5.4 Value Chain: Quantum Computers and Communication

GLOBAL

Quantum Computers

A.I. QUE Technologies, Alice & Bob, Anyon Technologies, AQT, ARQUE Systems, Atlantic Quantum, atom computing, bleximo, C12, diatope, DYNEX, diraq, Hewlett Packard Enterprise, IBM, Infleqtion, IQM, Microsoft, MIRAEX, NanoQT, NEQXT, oxford ionics, Pasqal, planqc, PsiQuantum, Q-CTRL, QUANFLUENCE, QUANTINUUM, Quantum Brilliance, QCi, qci, Quantum Machines, Quantum Source, QuEra, QUANDELA, QUIX Quantum, rigetti, seeqc, Silicon Quantum Computing, siquance, socionext, Turing, Universal Quantum, XEED

Quantum Communication

Aliro Quantum, American Binary, ANAMETRIC, ARQIT, Baidu 百度, ComScire, Crown Sterling, Crypta Labs, CryptoNext security, Crypto Quantique, CYBRANE, EYL, HEQA Security, QuantumXchange, IDQ, IQM, KETS, LEONARDO, MagiQ, MIRAEX, Post-Quantum, Q*bird, Q-CTRL, QPHOX, Qrypt, QUANTASTICA, QUANTINUUM, 国盾量子 QuantumCTek, QCi, quantum emotion, Quantum Opus, QUANTUMXCHANGE, Qubitekk, Quintessence Labs, socionext, SPARROW QUANTUM, Terra Quantum, Telefónica Tech, TOSHIBA, SOFTIRON

CANADA

Quantum Computers

ANYON, BTQ, D-Wave, Nord Quantique, Open Quantum Design, Photonic, Quantum Silicon, UQDevices, XANADU, Zero Point Cryogenics

Quantum Communication

BTQ, evolution, IRONCAP, ISARA, Photonic, QEYnet, quantropi, Quantum Bridge

TABLE OF CONTENTS

5.5 Value Chain: Quantum Software and QCaaS

GLOBAL

Quantum Software

algorithmiq, ARQUE SYSTEMS, Artificial Brain, ⟨b| e^iθ, BlueQubit, bqp, CLASSIQ, [commutator,studios], CryptoNext security, CYBRANE, Entropica Labs, Hewlett Packard Enterprise, horizon quantum, HQS Quantum Simulations, IBM, Infleqtion, KUANO, kvantify, MEGAZONE CLOUD, Microsoft, MULTIVERSE COMPUTING, NEQXT, NVIDIA, OQC, Pasqal, PHASECRAFT, POLARISqb, PsiQuantum, QCi QUANTUM COMPUTING INC, QCWARE, Q-CTRL, QUANDELA, Quantistry, QuantrolOx, QUANTUM BRILLIANCE, Quantum Inspire, QUANTUM MOTION, Qubit Pharmaceuticals, QuEra Computing Inc., QUNASYS, QW, river lane, SANDBOXAQ, STRANGEWORKS, Terra Quantum, ZAPATA, Zurich Instruments

Quantum Computing As a Service

A.I.QUE TECHNOLOGIES, AQT, Artificial Brain, aws Amazon Braket, ⟨b| e^iθ, BlueQubit, CLASSIQ, [commutator,studios], CYBRANE, DYNEX, EVIDEN, IBM, INSPIRATION·Q, IQM, KQC, MAGELLAN BLOCKS, MEGAZONE CLOUD, Microsoft, NEQXT, NVIDIA, ORIENTOM Investment & Consulting Inc., OQC, Pasqal, PIQUASSO, QILIMANJARO QUANTUM TECH, QUANDELA, QUANTASTICA, QUANTINUUM, Quantistry, QuEra Computing Inc., Quemix, QCi QUANTUM COMPUTING INC, Terra Quantum, ZAPATA

CANADA

Quantum Software

BTQ, CREATIVE DESTRUCTION LAB, CogniFrame The Hybrid Machine Learning Company, NANOACADEMIC TECHNOLOGIES Coherent Modeling, ProteinQure, 1QBit, softwareQ, XANADU

Quantum Computing As a Service

BTQ, CogniFrame The Hybrid Machine Learning Company, D-Wave, Nord Quantique, Open Quantum Design, Photonic, XANADU

5.6 Value Chain: Quantum Research Labs

GLOBAL

Quantum Research Labs

- A*STAR Quantum Innovation Centre (A*STAR Q.InC)
- Arque Systems
- Atomionics
- Baidu 百度
- Centre for Quantum Computation & Communication Technology
- Classiq
- CQT
- Google Quantum AI
- Hewlett Packard Enterprise
- IBM
- Intel Labs
- IonQ
- Leonardo
- Massachusetts Institute of Technology
- Megazone Cloud
- Microsoft
- Multiverse Computing
- NVIDIA
- Oak Ridge National Laboratory
- OQC
- Paris Centre for Quantum Technologies
- QAPPS
- QCi3 HUB
- Quantistry
- Qubitekk
- QUTE.sk Slovak National Center for Quantum Technologies
- QuTech
- Silicon Quantum Computing
- Sungkyunkwan University
- Sweden Quantum
- University of Warsaw Quantum Information Technologies Research Group
- Q-NEXT Next Generation Quantum Science and Engineering
- Universität Wien
- Zurich Instruments

CANADA

Quantum Research Labs

- Creative Destruction Lab
- FemtoQ
- H
- INRS Institut national de la recherche scientifique
- IQC Institute for Quantum Computing
- Institut Quantique UdS
- Quantum Alberta
- Stewart Blusson Quantum Matter Institute
- Quantum Valley Ideas Lab
- SQT

6

Patent Data Analysis

Over the last decade, quantum technologies have rapidly transitioned from the lab to the global innovation frontier. Patent data offers a unique window into this evolution, capturing where investments are being made, which entities are leading the charge, and how national strategies are shaping the global landscape. This section presents a detailed exploration of patent trends in quantum technologies, with a spotlight on Canada's role in the global context.

The tagging of the patents into respective technology tags is based on the technology as disclosed in the patent. A patent that discloses multiple technologies is tagged within multiple technology tags. Since the available data for the past 18 months might not be accurate and will only be available after patent publication, the downward trend after 2022 cannot be validated. Once the patent applications get published, the patent filing count from 2022 may show a steady increase, if not a significant increase.

Read more about the methodology here.

6

Patent Data Analysis (Table of Contents)

6.1 Patent Data Analysis: Overview (Global)

> **Note:** A patent family is defined as groups of related applications and granted patents across jurisdictions that share a common priority filing and cover the same or similar technical content.

Filing Trends

Global patent activity in quantum technologies has increased sharply over the past decade, reflecting the transition of quantum from an academic research area to a strategic technology domain. Filing levels were minimal prior to 2012, after which activity accelerated rapidly. From 2015 onward, annual filings grew steadily, culminating in a record year in **2022 with 10,380 patent families**. Between **2015 and 2022**, global quantum patent filings grew at an approximate **14% CAGR**, indicating sustained momentum rather than short-term experimentation.

Although global filing counts decline after 2022, this reduction is driven primarily by standard patent publication lags affecting recent years and does not indicate a slowdown in innovation. Overall, more than **83,000 quantum patent families** have been filed globally since 2005, with the strongest growth occurring in quantum computing, followed by quantum materials, quantum communications, and quantum sensing. Patent activity is concentrated in enabling technologies such as quantum hardware architectures, error correction, and system-level integration, highlighting a strong focus on near- to mid-term commercialization.

Key Jurisdictions

Quantum patent activity is highly concentrated geographically. **China** is the dominant jurisdiction, accounting for **52,361 patent families**, or approximately **63% of global filings**. Chinese activity is driven largely by universities, research institutes, and state-backed organizations, resulting in unmatched patent volume and domestic IP consolidation.

The **United States** ranks second with **16,648 patent families (20%)**, with filings led by large technology firms and defence-linked companies focused on scalable quantum computing systems and applied use cases. **South Korea** is the third-largest jurisdiction with **3,803 patent families (4.6%)**, followed by **Japan** with **1,770 patent families (2.1%)**, reflecting targeted industrial research rather than volume-driven strategies.

Overall, the global quantum patent landscape is characterized by China's overwhelming scale, a strong but smaller U.S. presence, and a long tail of countries with specialized but more limited patent activity.

6.1 Patent Data Analysis: Overview (Global)

Key Global Players

Global quantum patent activity is concentrated among a small group of well-resourced industrial firms, research institutions, and state-backed organizations. In China, patent ownership is dominated by universities and national research institutes such as the **Institute of Semiconductors (Chinese Academy of Sciences), Tsinghua University, and Zhejiang University**, alongside emerging companies including **Origin Quantum**. This reflects China's coordinated approach to domestic IP generation and technology self-reliance.

In the United States, patenting is largely industry-led, with **IBM, Google, Northrop Grumman, and Samsung** holding significant portfolios focused on scalable quantum computing systems, sensing, and system integration.

Across Asia and Europe, countries such as South Korea, Japan, and key European economies contribute smaller but strategically targeted portfolios, often aligned with specific hardware platforms, materials, or enabling technologies rather than high-volume filing strategies.

Key Technologies

Quantum computing accounts for the majority of global patent filings, with hardware architectures dominating activity. Among these, **superconducting qubits** represent approximately two-thirds of hardware-related patents, reflecting their relative maturity. Filing growth closely tracks major system deployments, **including IBM Quantum System One and Google's Sycamore processor. Photonic quantum computing** is gaining momentum, led by companies such as **Xanadu** and **PsiQuantum**, while **neutral atom and ion trap systems** are expanding particularly in the United States and Europe. In **quantum communications**, China leads patent activity, driven by extensive filings in **Quantum Key Distribution (QKD)** and secure networking, with strategic applications in defence and cybersecurity. **Quantum sensing and metrology** show steady growth due to near-term deployment potential, with activity from **IBM**, **Northrop Grumman**, and specialized startups such as **Atomionics**. In **quantum materials**, Asia dominates patenting, led by **Samsung**, **TCL**, and **BOE**, particularly in **quantum dot technologies** that underpin advances across computing, sensing, and optoelectronics.

6.2 Patent Data Analysis: Key Canadian Players

Key Canadian Players

Company	HQ	Primary Focus	Patent Strategy	Notable Highlights
D-Wave Quantum	Canada	Quantum annealing computing	U.S.-centric	Largest patent holder in quantum annealing, blockchain-secured quantum architecture
Xanadu Quantum	Canada	Photonic quantum computing	U.S., EU expansion	Filing surge post-2021, key partnerships with Japan and EU
1QB Technologies	Canada	Quantum software	North America; selective PCT filings	Enterprise partnerships; quantum-enabled drug discovery with Biogen/Accenture
National Research Council (NRC)	Canada	Quantum materials and computing	Balanced, public-sector-led	50+ quantum projects/year; strong domestic R&D engine
Zapata Quantum	USA/Canada	Quantum software & generative AI	U.S., Canada	AI-integrated quantum platforms, partnership with D-Wave
Anyon Systems	Canada	Quantum Computing	North America; selective PCT filings	Hardware development focused on scalable superconducting systems
Nord Quantique	Canada	Quantum Error correction	Global filings	Hardware-efficient error-corrected quantum architectures
Photonic	Canada	Spin-qubit Quantum Communication	PCT filings	Silicon-based spin-qubit architecture targeting fault-tolerant systems

6.3 Patent Data Analysis: Canada

Filing Trends in Canada

Quantum patents filed in Canada increased steadily from the early 2010s, reaching a peak around 2019, before declining and stabilizing at lower levels in subsequent years. This trajectory differs from leading jurisdictions such as the United States and China, where filing activity continued to grow through the early 2020s.

Patent activity in Canada is concentrated primarily in **quantum computing**, with secondary activity in **quantum materials**, and comparatively fewer filings in **quantum communications** and **quantum sensing**. Peak filing years were largely driven by foreign multinationals, notably **IBM**, **Google**, and **Northrop Grumman**, which consistently rank among the most active assignees in Canada. These filings appear to be strategic extensions of global portfolios, aimed at securing freedom to operate and defensive coverage in a credible research jurisdiction, rather than reflecting Canada as a core commercialization market.

Canadian-headquartered companies account for a smaller share of total filings within Canada, and overall filing intensity remains modest relative to peer innovation economies. Since 2020, there is limited evidence of renewed acceleration in domestic patenting activity, particularly from industry. This positions Canada primarily as a **secondary filing jurisdiction**, valued for its scientific ecosystem and legal stability, but not as a leading source of sustained patent origination in quantum technologies.

6.3 Patent Data Analysis: Canada (Continued)

*D-Wave was founded in Canada and retains significant operations in British Columbia. Despite the relocation of certain corporate functions to the United States for funding and market access, the company is categorized as Canadian in this study based on its origin and continued operational footprint in Canada.

Canadian Patent Ownership

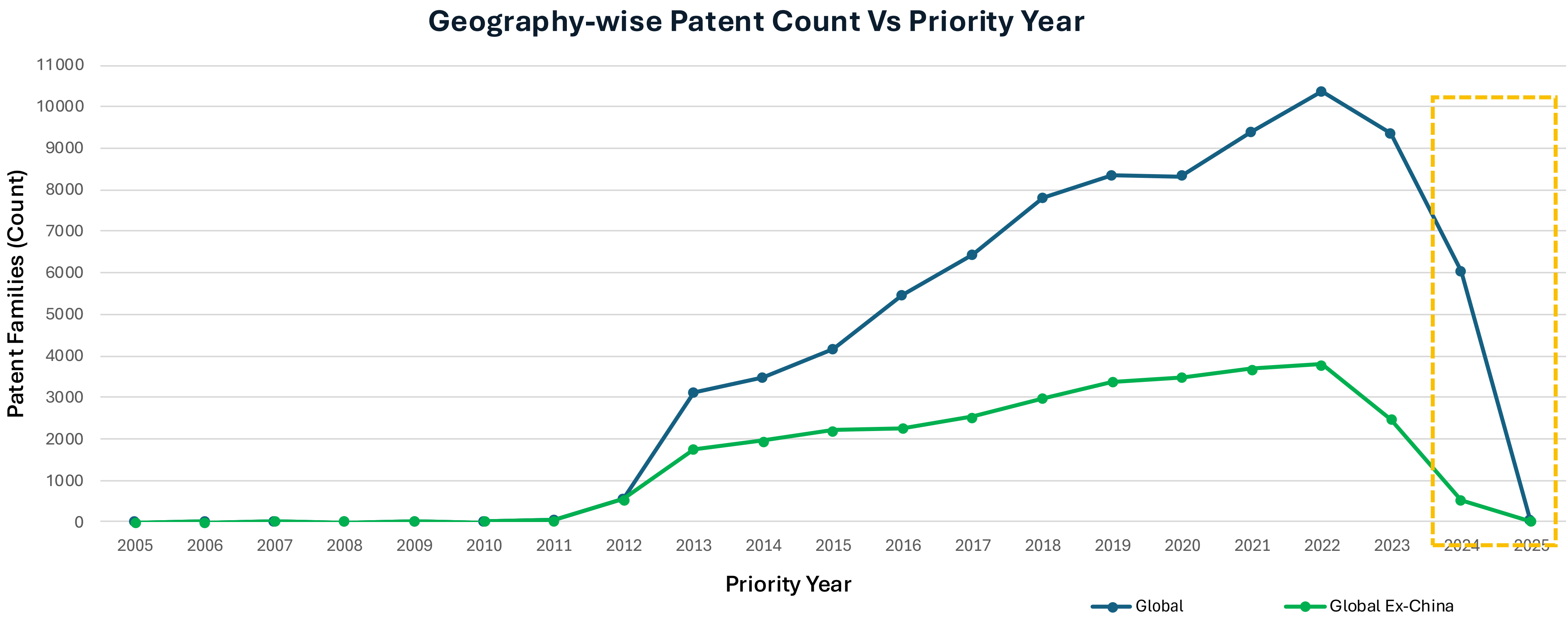
***D-Wave Quantum** is the largest Canadian-owned holder of quantum intellectual property, with approximately **111 patent families** globally, primarily focused on quantum computing and quantum annealing architectures. This position reflects D-Wave's status as one of the earliest commercial entrants in the quantum sector, with patent activity dating back to its founding in 1999. Its portfolio represents more than two decades of sustained investment in a technology domain that remains largely pre-commercial at scale. The concentration of D-Wave's patents in the United States and other key countries aligns with its commercialization strategy and target markets, rather than indicating constraints in Canadian innovation capacity.

Beyond D-Wave, Canadian private-sector ownership of quantum IP declines sharply, a pattern consistent with the infant-stage nature of the global quantum industry. Firms such as **Xanadu** and **1QBit** maintain smaller but strategically focused patent portfolios concentrated in quantum software, algorithms, and photonic computing. Their filings are primarily directed toward the United States and select international countries in anticipation of future market formation, partnerships, and platform adoption. The absence of large-scale patent portfolios among other Canadian firms mirrors global conditions, as few countries have produced quantum companies operating at meaningful commercial scale.

Public-sector institutions play a central role in Canadian-owned quantum IP at foundational stages. The **National Research Council of Canada** and leading universities, including the **University of Toronto** and the **University of British Columbia**, contribute early-stage patents designed to support licensing, technology transfer, and long-term ecosystem development rather than immediate commercialization.

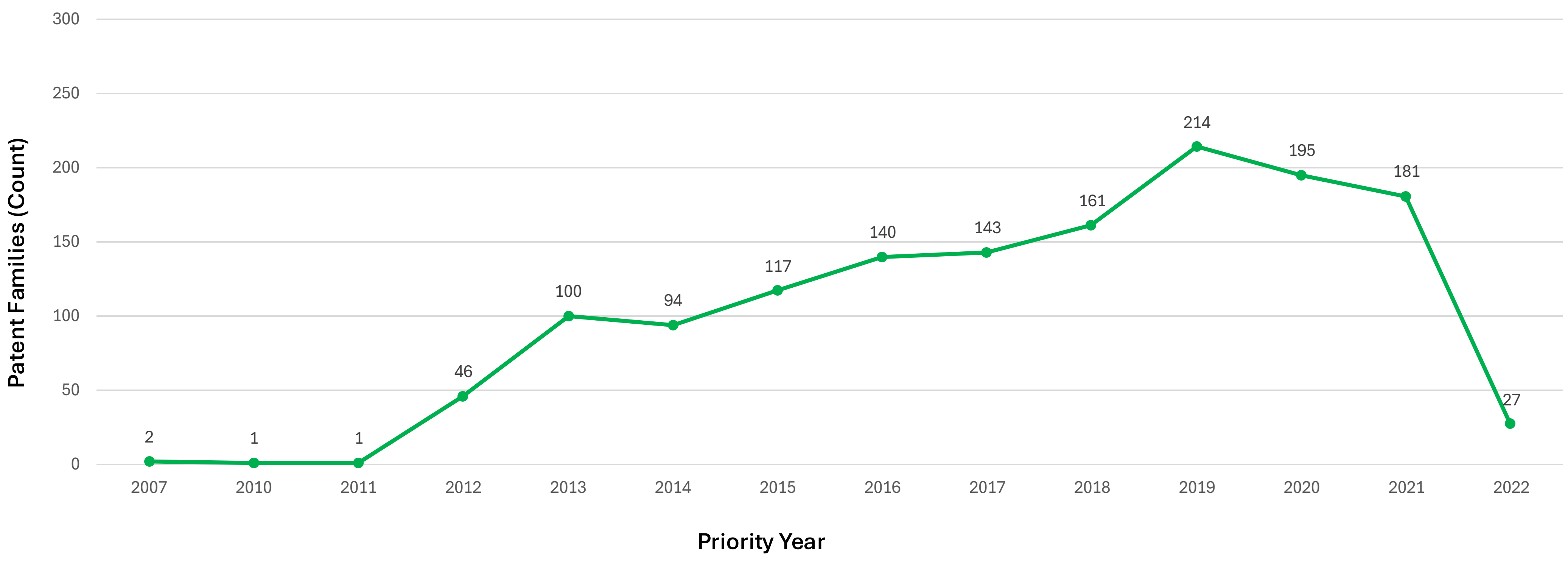
Overall, Canadian quantum IP ownership reflects a small number of early private-sector pioneers and strong public research institutions, aligned with the broader reality that quantum technologies remain an infant industry globally.

6.4 Yearly Filing Trends: Global



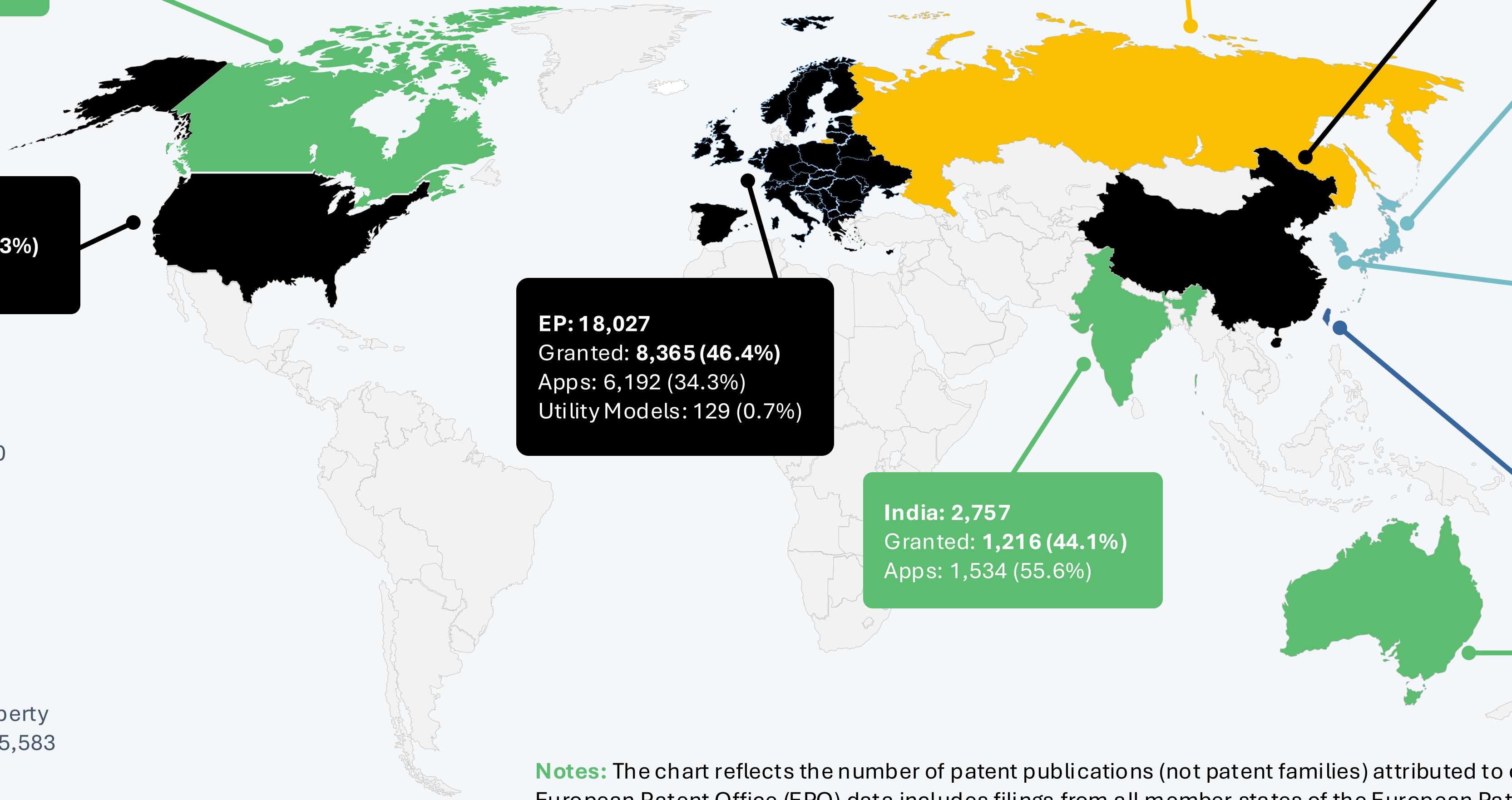
Note: Patent counts for 2024–2025 may increase as applications are published up to 18 months after the earliest filing date. The graphic shows worldwide patent filings, both including and excluding filings with the China National Intellectual Property Administration (CNIPA). All counts represent **unique patent families**, defined as groups of related applications and granted patents across jurisdictions that share a common priority filing and cover the same or similar technical content.

6.5 Yearly Filing Trends: Canada



Note: Patent counts for 2024–2025 may increase as applications are published up to 18 months after the earliest filing date.
The graphic shows patent filings with the Canadian Intellectual Property Office (CIPO). All counts represent **unique patent families**, defined as groups of related applications and granted patents across jurisdictions that share a common priority filing and cover the same or similar technical content.

6.6 Geographical Filing Trend: Legal Status & Utility Models



Canada: 2001
Granted: **866 (43.2%)**
Apps: 937 (46.8%)

USA: 37,802
Granted: **26,966 (71.3%)**
Apps: 6,676 (17.7%)

EP: 18,027
Granted: **8,365 (46.4%)**
Apps: 6,192 (34.3%)
Utility Models: 129 (0.7%)

Russia: 1,241
Granted: **869 (70%)**
Apps: 104 (8.4%)
Utility Models: 125 (10%)

India: 2,757
Granted: **1,216 (44.1%)**
Apps: 1,534 (55.6%)

China: 88,687
Granted: **51,712 (58.3%)**
Apps: 19,144 (21.6%)
Utility Models: 6,236 (7%)

Japan: 12,668
Granted: **8,358 (66%)**
Apps: 2,516 (19.9%)
Utility Models: 26 (0.2%)

Republic of Korea: 13,432
Granted: **9,132 (68%)**
Apps: 3,213 (24%)
Utility Models: 7 (0.05%)

Taiwan: 5,114
Granted: **3,571 (69.8%)**
Apps: 1,078 (21.1%)
Utility Models: 243 (4.75%)

AU: 2,363
Granted: **1,452 (61.4%)**
Apps: 490 (20.7%)

NO. OF PATENTS

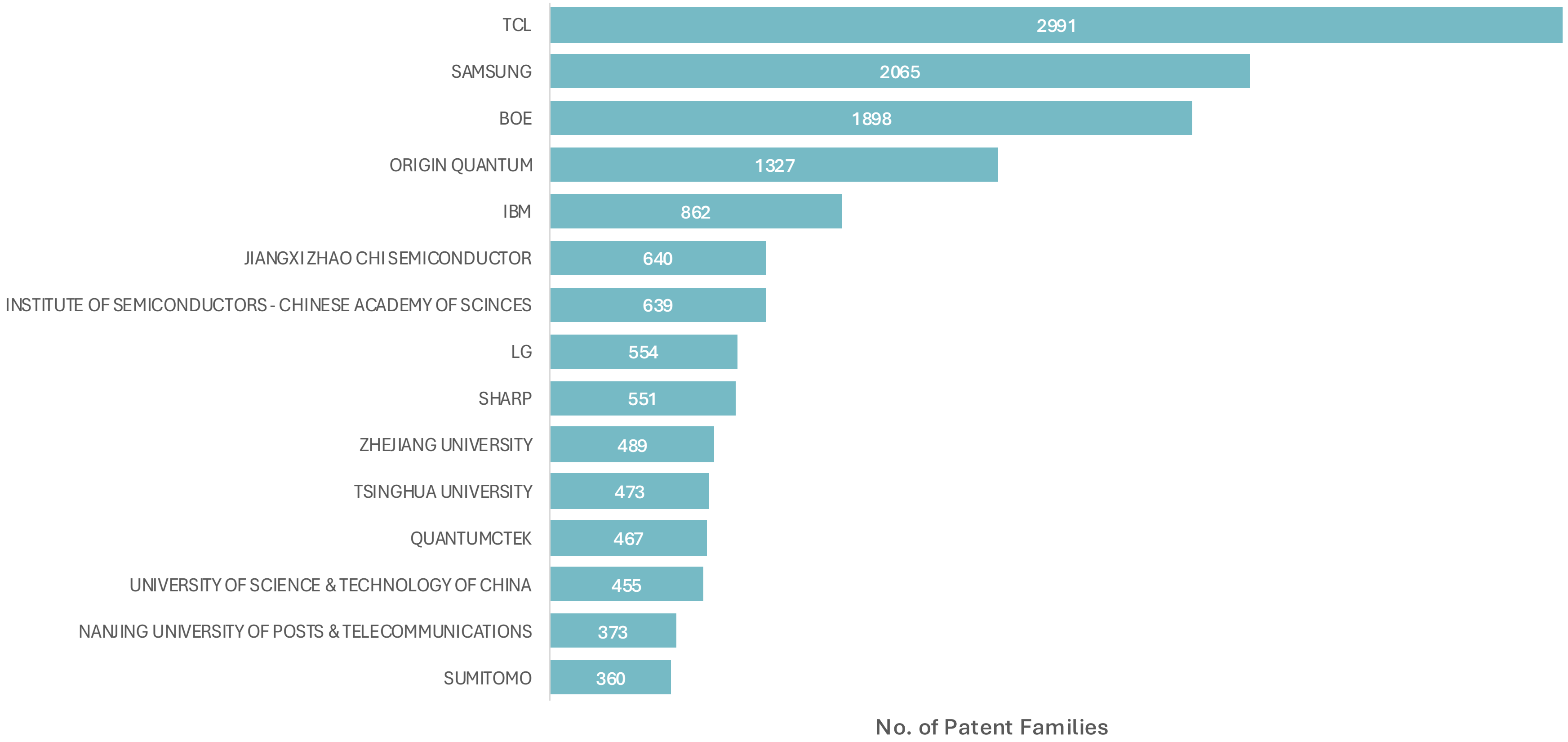
- More than 15,000
- 6,001 – 15,000
- 4,001 – 6,000
- 2,001 – 4,000
- Less than 2,000

World Intellectual Property Organization (WIPO) 15,583

Notes: The chart reflects the number of patent publications (not patent families) attributed to each country shown. European Patent Office (EPO) data includes filings from all member states of the European Patent Organization. Total patent records comprise granted patents, active pending applications, and utility patents; expired and other inactive filings account for the remaining difference.

IAC CAI | QUANTUM ALGORITHMS INSTITUTE

6.7 Top Assignees: Global



Note: Chart based on patent families, defined as groups of related applications and granted patents across jurisdictions that share a common priority filing and cover the same or similar technical content.

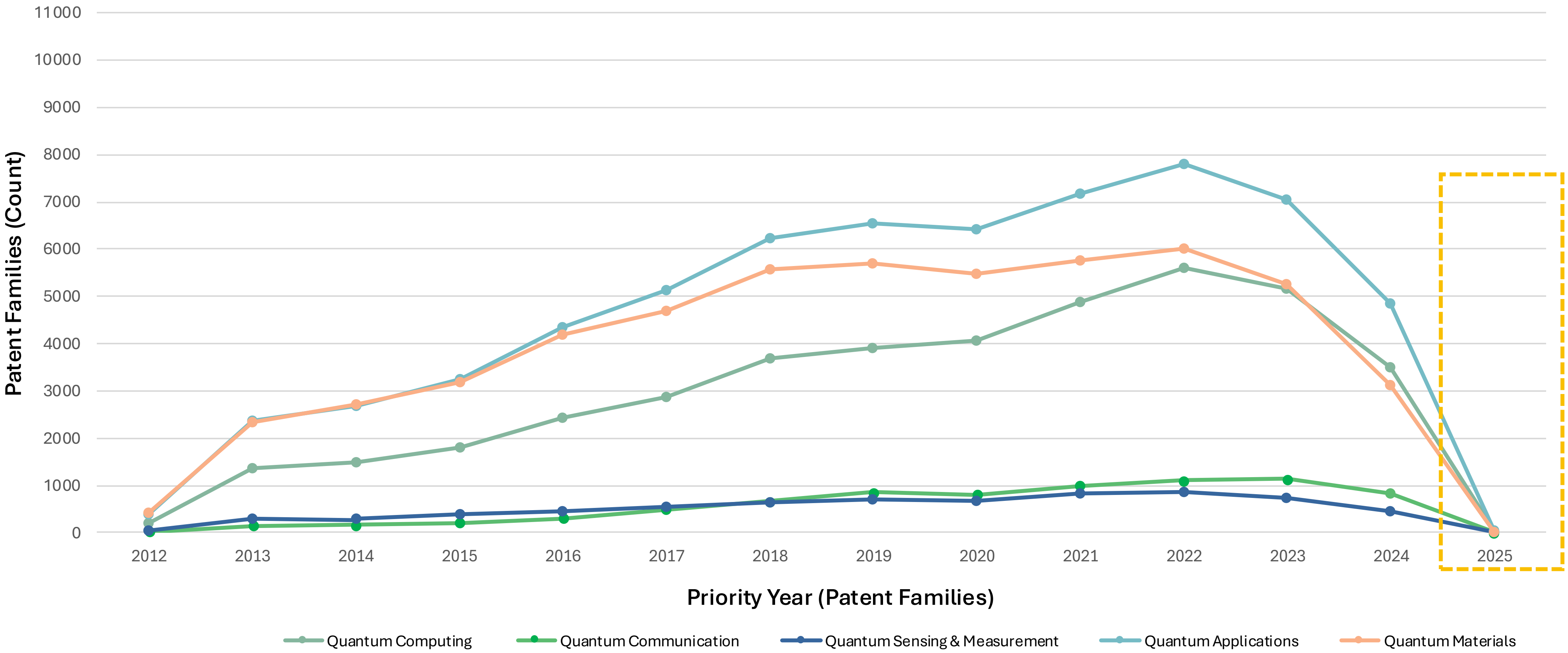
6.8 Yearly Filing Trends for Top 10 Corporate Assignees (Global)

Priority Year →

ASSIGNEE/PRIORITY YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
TCL	20	37	172	261	467	405	421	359	337	355	139	18	0
SAMSUNG	81	136	131	171	164	212	226	265	243	219	176	0	0
BOE	72	67	98	166	163	266	223	220	265	181	141	36	0
ORIGIN QUANTUM	0	0	0	0	4	40	70	100	293	408	336	76	0
IBM	17	13	33	24	49	105	144	139	134	140	62	0	0
JIANGXI ZHAO CHI SEMICONDUCTOR	0	0	0	1	1	14	11	2	9	160	317	125	0
LG	53	88	65	53	47	38	57	39	37	41	31	2	0
SHARP	8	11	29	12	31	55	92	109	86	74	40	0	0
QUANTUMCTEK	17	5	7	23	53	70	70	103	57	48	12	2	0
SUMITOMO	34	35	35	33	58	44	39	44	10	21	7	0	0

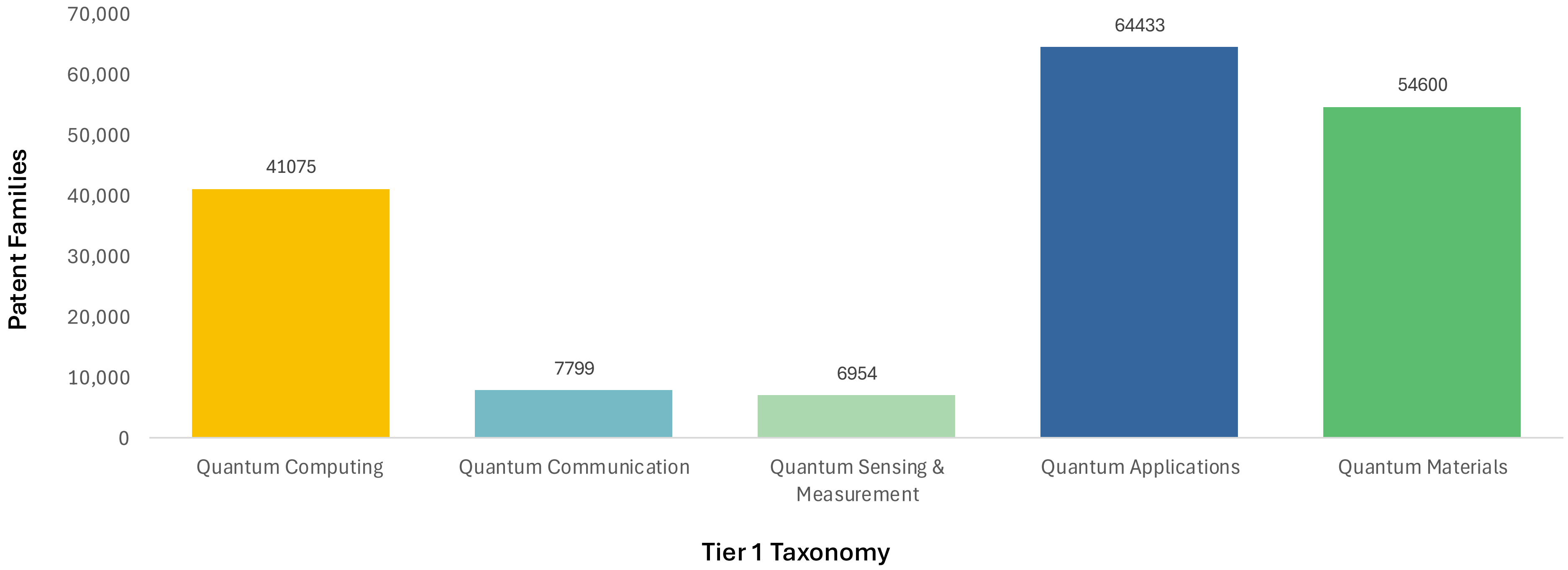
Note: The table shows the yearly patent filings (based on patent families) by the top global corporate assignees.

6.9 Yearly Filing Trends by Technology (Global)



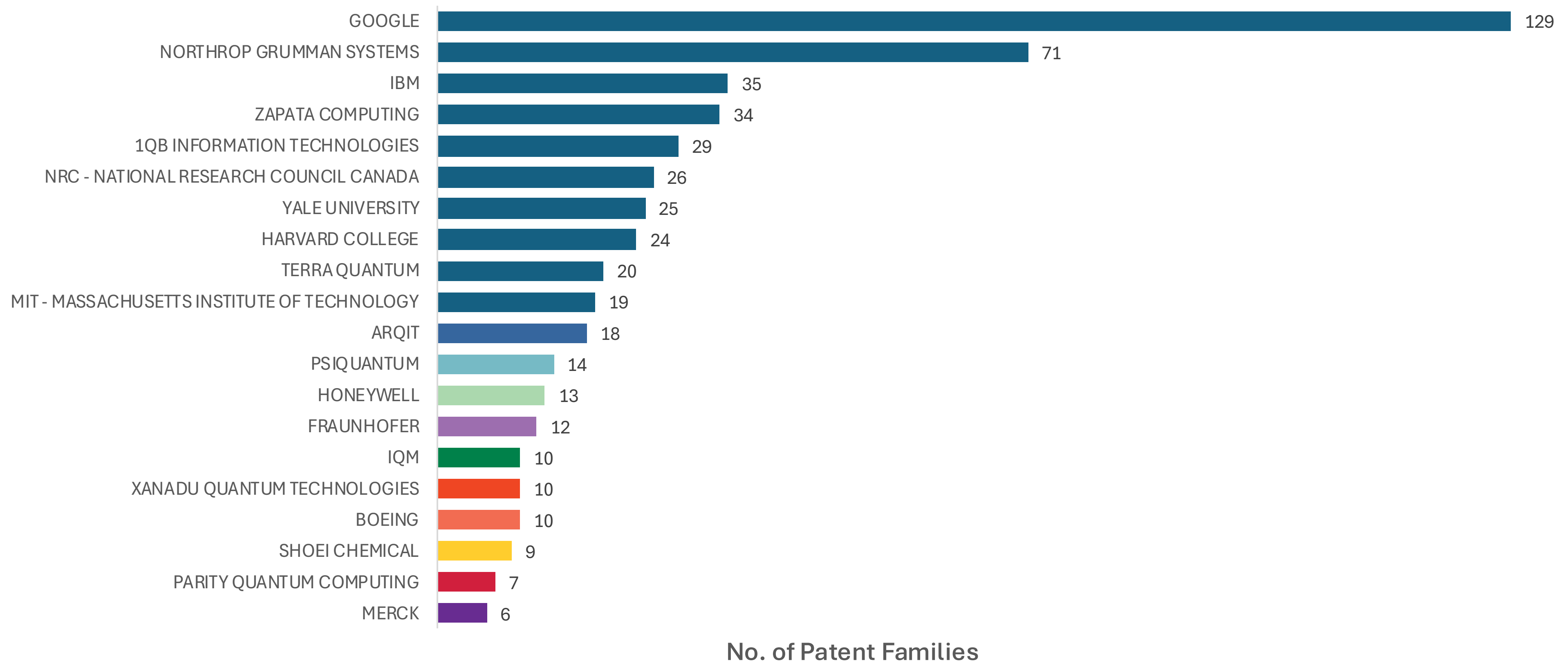
Note: The number of patent applications for 2024 & 2025 may increase as the applications get published 18 months from the earliest filing date.
The mapping of patents to technology areas is not mutually exclusive, that means a single patent may be tagged in one or more technology areas.

6.10 Technology-wise filing trends (Global)



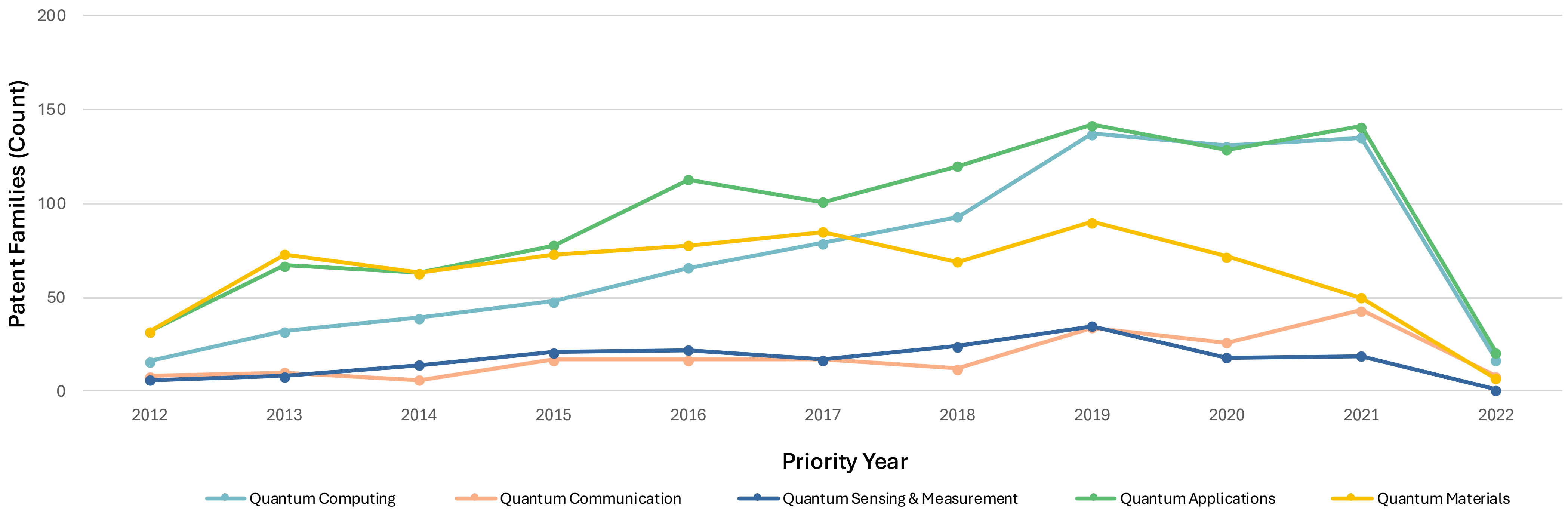
Note: The mapping of patents to technology areas is not mutually exclusive, that means a single patent may be tagged in one or more technology areas.

6.11 Top Assignees: Canada



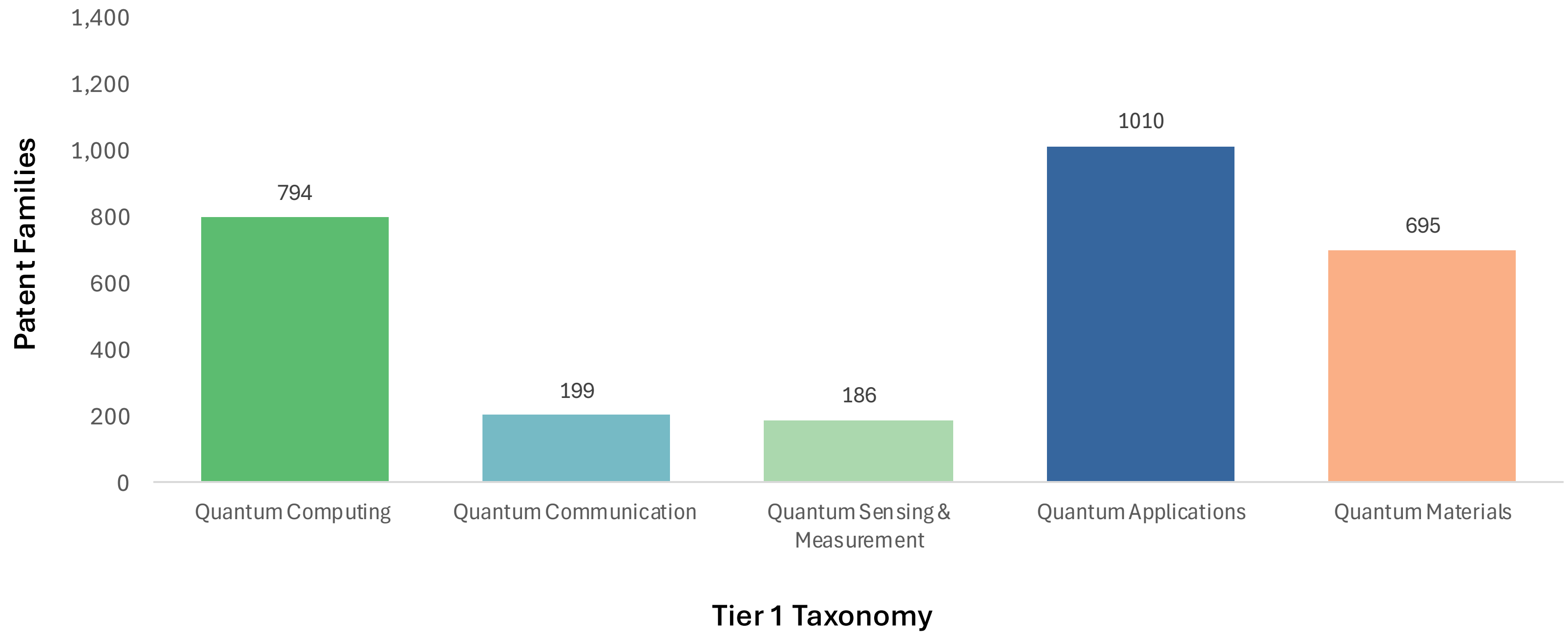
Note: This graphic highlights the leading companies filing patent applications in Canada and is based on patent families.

6.12 Yearly Filing Trends by Technology (Canada)



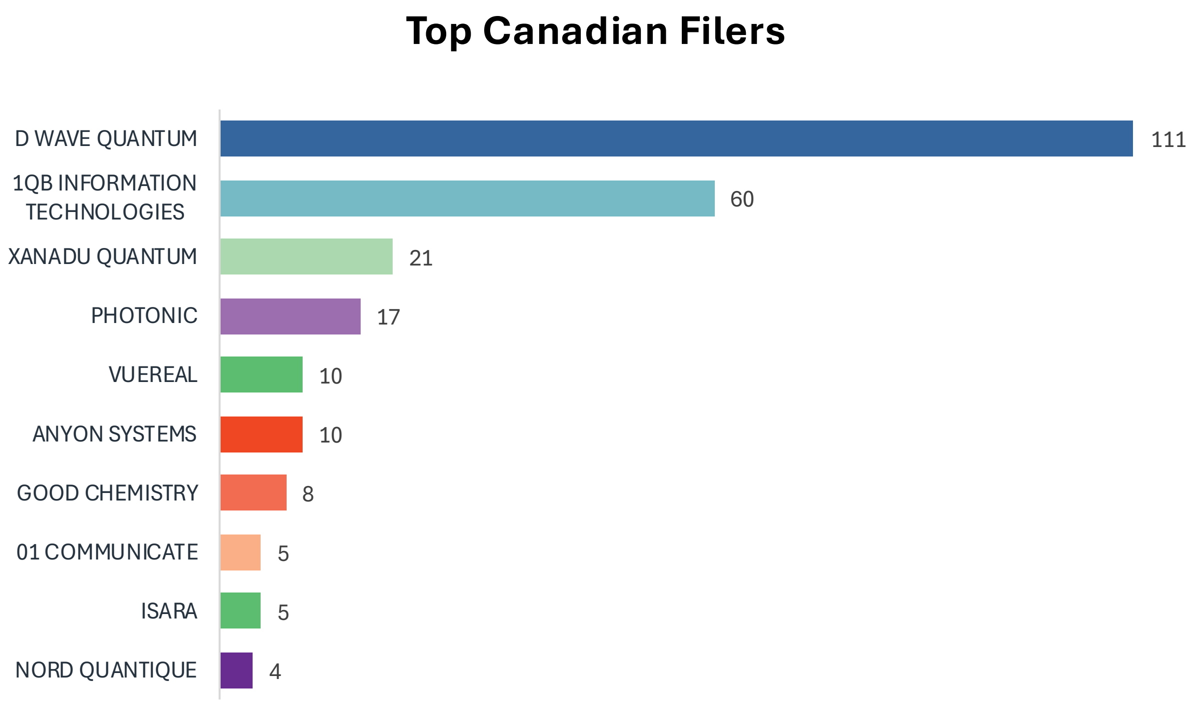
Note: The mapping of patents to technology areas is not mutually exclusive, that means a single patent may be tagged in one or more technology areas. Chart based on patent families.

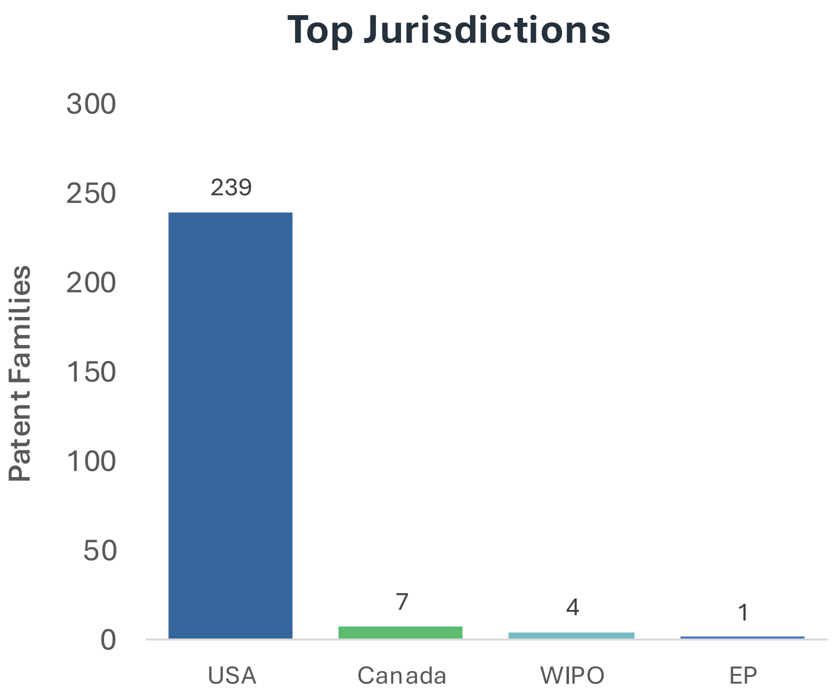
6.13 Technology-wise filing trends (Canada)



Note: The mapping of patents to technology areas is not mutually exclusive, that means a single patent may be tagged in one or more technology areas.

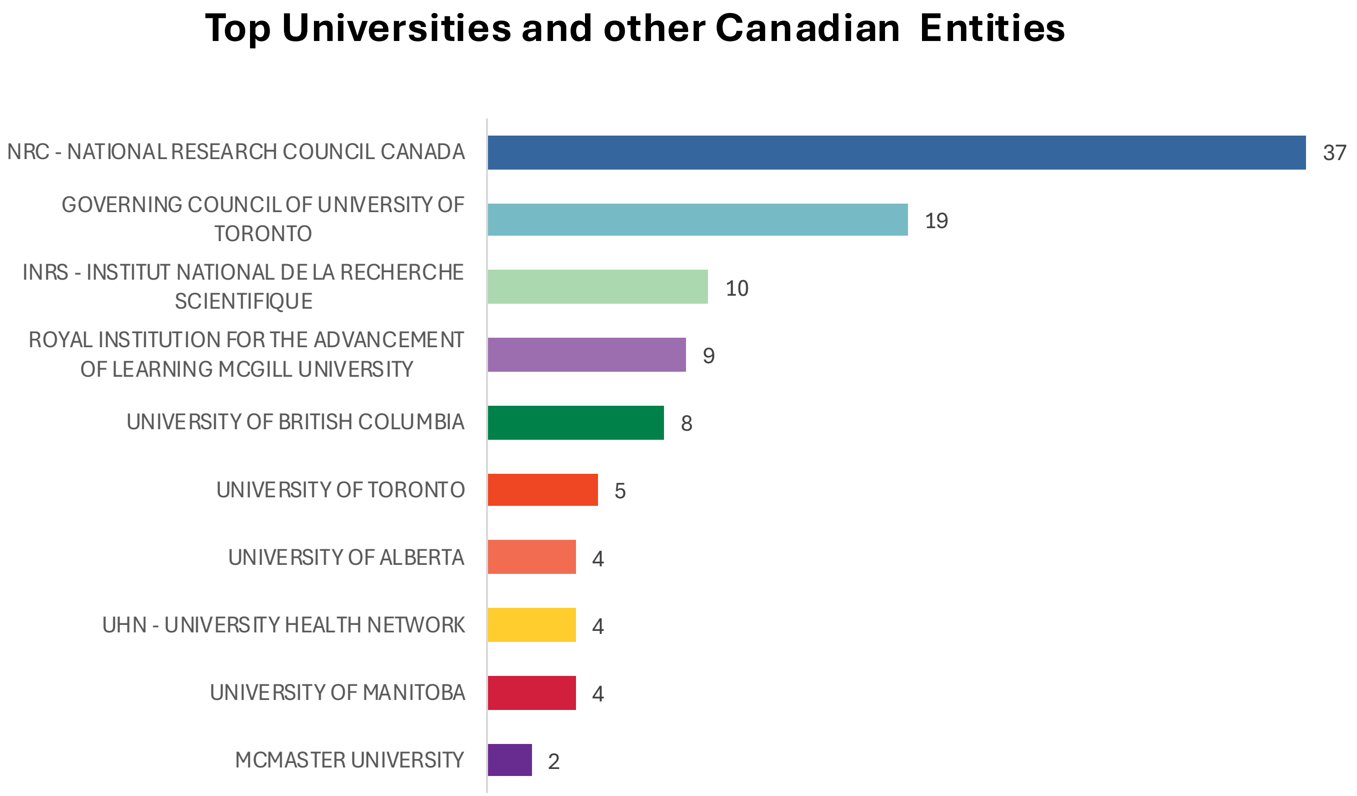
6.14 Top Canadian Corporate Assignees & Jurisdictions

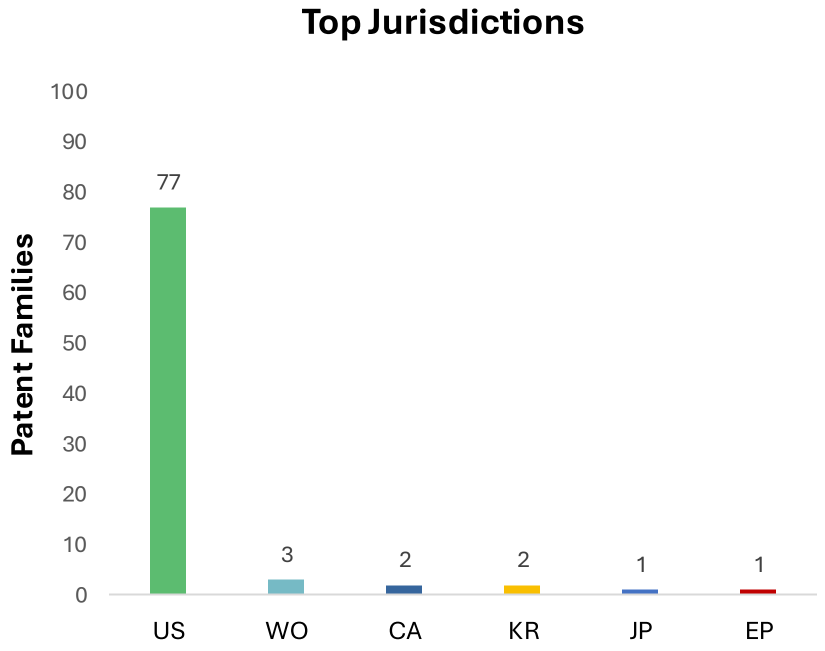




Note: The graphics highlight leading Canadian corporate assignees and the jurisdictions in which they filed patents globally. Both charts are based on patent families.

6.15 Top Canadian Universities and Other Entities





Note: The graphics highlight leading Canadian universities and research institutes and the jurisdictions in which they filed patents globally. Both charts are based on patent families.

6.16 Filing Trends: Quantum Computing

Filing Trends

- 41,075 patent families (49.4% of the patent families)
- There was a steep rise in filings from 2014

Key Technologies

- Fundamental Principles (20,359)
- Quantum Infrastructure (16,747)
- Quantum Control Systems (12,704)
- Quantum Hardware/Qubit technologies (5,369)
- Quantum Software (3,084)

Key Filers

- Origin Quantum (1,235)
- TCL (1,195)
- IBM (777)
- BOE (756)
- Samsung (561)

Key Jurisdictions

- China (28,030)
- USA (5,227)
- Republic of Korea (2,412)
- Japan (1,410)
- PCT (859)
- Canada (29)

Note: The information reflects patents filed from 2013 onward. Filing jurisdictions indicate where assignees have sought patent protection; for example, *USA (5,227)* denotes the number of filings submitted to the United States Patent and Trademark Office (USPTO).

6.17 Filing Trends: Quantum Communication

Filing Trends

- 7,799 patent families (9.3% of the patent families)
- There was a steep rise in filings from 2016

Key Technologies

- Quantum Cryptography/Quantum-Safe Encryption (3,198)
- Quantum Networking (3,771)
- Quantum Communication Protocols (404)
- Quantum Communication Hardware (1,380)

Key Filers

- Quantumctek (216)
- Origin Quantum (100)
- Tsinghua University (98)
- National Quantum Communication Guangdong (94)
- University Of Science & Technology Of China (94)

Key Jurisdictions

- China (5,127)
- USA (1,082)
- Republic of Korea (380)
- India (206)
- Japan (193)
- Canada (9)

Note: The information reflects patents filed from 2013 onward. Filing jurisdictions indicate where assignees have sought patent protection; for example, *Canada (9)* denotes the number of filings submitted to the Canadian Intellectual Property Office (CIPO).

6.18 Filing Trends: Quantum Sensing & Measurement

Filing Trends

- 6,954 patent families (8.3% of the patent families)
- While starting slower, Quantum Sensing & Measurement showed steady growth, particularly from 2015 onwards

Key Technologies

- Quantum Metrology (1,952)
- Quantum Imaging (1,105)
- Quantum Sensing Technologies (4,799)
- Quantum Image Processing (39)

Key Filers

- Shanghai Institute Of Microsystem & Information Technology (129)
- Origin Quantum (104)
- University of Science & Technology of China (70)
- IBM (65)
- Samsung (61)

Key Jurisdictions

- China (4,212)
- USA (1,046)
- Republic of Korea (396)
- Japan (384)
- Russian Federation (171)
- Canada (5)

Note: The information reflects patents filed from 2013 onward. Filing jurisdictions indicate where assignees have sought patent protection; for example, *Canada (5)* denotes the number of filings submitted to the Canadian Intellectual Property Office (CIPO).

6.19 Filing Trends: Quantum Applications

Filing Trends

- 64,433 patent families (77.5 % of the patent families)
- Quantum Applications consistently show the highest number of patent filings globally since around 2015, peaking around 2022

Key Technologies

- Chemistry & Material Science (28,757)
- Communication (25,139)
- Display & Lighting (18,696)
- Quantum Cryptographic Applications (7,887)
- Artificial Intelligence (7,218)

Key Filers

- TCL (2,676)
- BOE (1,569)
- Samsung (1,382)
- Origin Quantum (652)
- Jiangxi Zhao Chi Semiconductor (514)

Key Jurisdictions

- China (44,416)
- USA (6,562)
- Republic of Korea (4,572)
- Japan (2,308)
- PCT (1,316)
- Canada (38)

Note: The information reflects patents filed from 2013 onward. Filing jurisdictions indicate where assignees have sought patent protection; for example, *Canada (38)* denotes the number of filings submitted to the Canadian Intellectual Property Office (CIPO).

6.20 Filing Trends: Quantum Materials

Filing Trends

- 54,600 patent families (65.7 % of the patent families)
- Quantum Materials has shown steady and significant growth since 2012-2013

Key Technologies

- Quantum Dots (41,292)
- Quantum Well (13,272)
- Topological Insulators (2,704)
- Graphene (5,187)
- Superconductors (709)

Key Filers

- TCL (2,947)
- Samsung (1,958)
- BOE (1,867)
- Jiangxi Zhao Chi Semiconductor (638)
- Institute of Semiconductors - Chinese Academy of Sciences (598)

Key Jurisdictions

- China (36,552)
- Republic of Korea (5,262)
- USA (5,243)
- Japan (2,301)
- PCT (1,299)
- Canada (17)

Note: The information reflects patents filed from 2013 onward. Filing jurisdictions indicate where assignees have sought patent protection; for example, *Canada (17)* denotes the number of filings submitted to the Canadian Intellectual Property Office (CIPO).

7

Market Assessment

7.1 Market Overview

Quantum Technologies Moving from Development to Early Deployment

Quantum computing applications in chemicals, life sciences, finance, and mobility are emerging as a potential driver of structural change in the modern economy. Including computing, communications, and sensing, quantum technologies are moving from lab experiments into early commercial deployment. Governments and large enterprises now treat quantum as strategic infrastructure on par with AI and advanced semiconductors. The 2025 Quantum Economic Development Consortium (QED-C) report estimates that the global quantum technology market reached over **US $1.45 billion in 2024**, highlighting nascent but accelerating commercialization.

Technology Roadmaps and Emerging Commercial Applications

Key signals of market traction in quantum technologies include accelerating hardware roadmaps from leading firms such as IBM, Google, Microsoft, IonQ, Rigetti, PsiQuantum, and Pasqal, many of which target fault-tolerant quantum systems in the early-to-mid 2030s. At the same time, commercial pilots are expanding across optimization use cases (e.g., finance, logistics, and grid operations), quantum-enhanced simulation for materials, catalysis, and batteries, and quantum-inspired algorithms running on classical hardware. While the ecosystem remains early-stage and concentrated, expectations are growing that practical quantum advantage for selected problems could emerge within this decade, unlocking new value pools while also posing disruptive implications for cybersecurity.

Challenges & Strategic Needs

Despite rapid progress, quantum technologies remain constrained by **high error rates**, **limited scalability**, and unresolved challenges in **fault tolerance** and **systems integration**. Talent shortages, fragmented standards, and uncertain commercialization timelines further slow adoption. Addressing these gaps will require sustained public investment, coordinated ecosystem development, and early preparation for quantum-safe security transitions.

7.2 Key Market Drivers

Quantum-Enabled Modeling and Optimization of Complex Systems

Quantum computing and quantum simulation are expected to enable more accurate modeling of complex physical and chemical systems that are intractable for classical computers. According to recent industry assessments and patent data analysis, the most advanced near-term applications focus on materials science, battery chemistry, molecular simulation, and drug discovery, with longer-term potential for broader climate and energy system modeling. These capabilities are driving early demand from the energy, materials, chemicals, life sciences, and sustainability sectors, particularly through hybrid classical-quantum workflows and cloud-based access to quantum hardware.

Defense, Security and Sovereignty

Governments view quantum technologies as strategic infrastructure with implications for secure communications, cryptography, and sensing. National strategies embed quantum as a priority for economic and national security competitiveness. The OECD notes that many national quantum roadmaps explicitly link public investment to security and industrial competitiveness goals.

Industrial Digitization and New Business Models

Quantum technologies are transitioning from lab research to commercialization through cloud-based access, Quantum-as-a-Service, and hybrid classical-quantum workflows. Commercial pilots in finance, logistics, healthcare, and supply chain optimization are signalling early industry uptake.

Policy and Global Market Expansion

Over 30 countries now have formal national quantum strategies with long-term funding, coordination mechanisms, and mission goals that align public, private, and academic stakeholders. These strategies aim to reduce fragmentation and enable scalable commercialization and workforce development.

7.3 Key Technology Drivers

Error Correction and Control Engineering

Quantum error correction and control systems are central to advancing qubit quality, with hardware and software co-design playing a key role in closing gaps toward fault-tolerant systems. As demonstrated by Microsoft's qubit-virtualization system and Quantinuum's ion-trap hardware used to run 14,000+ experiments without a single error, the world is moving beyond the NISQ (Noisy intermediate-scale quantum) era.

Quantum Sensing and Metrology

With significant breakthroughs in 2024 and early 2025, quantum sensing is moving beyond foundational research. This is evidenced by NASA's demonstration of an ultracold quantum sensor in space, NRC's research to advance photonic-based quantum sensing technologies that will be integrated onto chips, and several other innovations globally on quantum sensors involving cold atoms and use cases such as diamond-based microscopy for semiconductor analysis, inertial navigation without GPS and underground resource mapping.

Quantum Communication and Networking

Quantum key distribution (QKD) and quantum-secured networks are being deployed in Europe and Asia and piloted in North America, often integrated with existing fibre and satellite infrastructure.

AI, Software, and Standards

AI aided by machine learning has the potential to drive material discovery through expedited quantum hardware development. Software layers (compilers, optimizers, emulators) are increasingly hardware-agnostic, enabling cross-platform benchmarking and portability. Standards bodies and agencies (e.g., NIST, ISO/IEC, ETSI) are starting to define benchmarks, security standards, and post-quantum cryptography schemes, which will shape commercial adoption.

7.4 Policies & Initiatives: USA

What SMEs need to know: The US offers deep R&D funding, strong university–industry consortia, and open cloud access to leading hardware. SMEs benefit from SBIR/STTR and QED-C-coordinated programs but must navigate export controls, cybersecurity rules, and evolving PQC standards.

United States: Leadership Through the National Quantum Initiative

The United States remains one of the largest and most dynamic quantum markets, driven by a mix of federal investment and private-sector leadership (Big Tech and specialized start-ups). With many quantum technologies still being in the nascent stages but showing promise, private investments involve significant risks. Governments globally, and especially the US government are investing to supplement the role of private funding. The National Quantum Initiative Act (2018) established a coordinated 10-year federal program across The National Science Foundation (NSF), The Department of Energy (DOE), The National Institute of Standards and Technology (NIST) and other agencies to advance quantum information science (QIS). DOE and NSF have funded national quantum centers, while NIST leads measurement science, PQC standards, and the Quantum Economic Development Consortium (QED-C) to coordinate industry.

Dual-Use Technologies

The US government explicitly recognizes quantum technologies as dual-use i.e., they can drive both **economic innovation** and **national security** capabilities while also presenting **strategic risks** that must be managed. Under the National Quantum Initiative (NQI) framework, federal agencies coordinate research and development across quantum computing, communications, and sensing with an emphasis on protecting intellectual property, understanding dual-use implications, and supporting national-security-relevant applications from basic science through commercialization. Defense and intelligence agencies Defense Advanced Research Projects Agency (DARPA) and Department of Defense (DoD), and The National Security Agency (NSA) support dual-use applications and ensure strategic advantage in cryptography, sensing, and secure communications.

7.4 Policies & Initiatives: USA

The Quantum Benchmarking Initiative (QBI)

The Quantum Benchmarking Initiative (QBI) is a multi-stage R&D program launched in July 2024 by the DARPA and DoE to rigorously evaluate whether any current quantum computing approach can be engineered into an industrial-grade **fault-tolerant quantum computer by 2033**. The initiative builds on DARPA's earlier Underexplored Systems for Utility-Scale Quantum Computing (US2QC) program and brings together a diverse cohort of global quantum companies, spanning superconducting, trapped-ion, photonic, and silicon spin qubit architectures, to articulate technical concepts, risk-mitigated R&D plans, and ultimately undergo independent verification and validation toward scalable hardware. Several companies including Atom Computing, Diraq, Canadian companies Nord Quantique, Photonic Inc. and Xanadu have already been selected for Stage B as of November 7, 2025.

Incentives:

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) initiatives in conjunction with DOE and NSF grants, and state-level innovation funds focused on quantum and advanced computing can be leveraged by SMEs focusing on quantum and advanced computing.

Regulatory Framework:

The US is at the forefront of post-quantum cryptography migration, with NIST's finalized PQC standards and federal guidance driving early adoption across government and critical infrastructure. Export controls and security policies increasingly treat quantum technologies as strategic, affecting cross-border collaborations and supply chains, particularly vis-à-vis China.

7.5 Policies & Initiatives: Europe

What SMEs need to know: Europe combines strong public funding, coordinated EU-wide initiatives, and leading academic hubs. SMEs benefit from open-science culture, shared testbeds, and strong IP frameworks but must track evolving EU security, data, and investment-screening rules.

European Union: Quantum Flagship and EU Quantum Strategy

The EU Quantum Technologies Flagship is a long-term $1.17 billion initiative to support quantum computing, communications, and sensing research and industrialization across Europe. In 2025, the EU introduced an EU Quantum Strategy, reporting more than $13 billion in public quantum funding over the previous five years and announcing plans for a **"Quantum Act"** to attract private capital, protect start-ups, and strengthen dual-use capabilities. Pan-European initiatives such as EuroQCI aim to deploy a secure quantum communications infrastructure combining terrestrial fibre and satellites.

Incentives & National Programs:

Germany, France, the Netherlands, and others run multi-billion-euro national quantum programs, often focused on building universal quantum computers and quantum hubs. The UK (outside the EU but part of the European quantum landscape) has a long-running National Quantum Technologies Programme and a 10-year National Quantum Strategy with multi-billion-pound commitments.

Regulatory Framework and Open-Data Policy:

The EU is active in standards, export controls, and ethical frameworks for emerging technologies, including quantum, through initiatives under the Digital Strategy and related regulations.

7.6 Policies & Initiatives: China

What SMEs need to know: China offers very large public funding and rapid infrastructure build-out, but the ecosystem is highly centralized and tightly regulated. Foreign and joint-venture SMEs must navigate complex licensing, cybersecurity, and data-localization rules.

China: State-Led Push in Quantum Technologies

China is pioneering efforts in quantum technologies both in terms of national alignment through policies and incentives as well as patenting key technologies. Quantum technologies are identified as "frontier" strategic technologies in China's 13th and 14th Five-Year Plans, linked to military-civil fusion and national security. Further, estimates suggest that China has announced public quantum investments of roughly $4-15 billion, making it one of the largest state funders globally. China has laid emphasis on nationalizing and coordinating united efforts in progressing quantum technologies as Government-linked labs dominate quantum communications (e.g., satellite QKD demonstrations) and large-scale infrastructure, while many private quantum labs have been consolidated or shuttered to centralize control.

Incentives:

Provincial and municipal governments support quantum hubs (e.g., Hefei, Beijing, Shanghai) via research parks, subsidies, and long-term procurement commitments. A national venture capital guidance fund aims to mobilize trillions of yuan in high-tech sectors including quantum, semiconductors, AI, and energy.

Regulatory Framework:

Quantum research and deployment are governed by Cybersecurity, Data Security, and Cryptography laws, with strict controls on cross-border data transfer and export of advanced technologies.

7.7 Policies & Initiatives: Asia

What SMEs need to know: Japan, South Korea, Singapore and others are building well-funded, partnership-oriented quantum hubs with strong emphasis on standards, industrialization, and international collaboration.

Japan: Structured Expansion and Industrial Strategy

Leading the quantum charge with establishing international standardization of quantum benchmarks, Japan released a Quantum Technology and Innovation Strategy (2020) and a Vision of Quantum Future Society (2022), targeting 10 million quantum users and about $330 billion in QT production by 2030, alongside the creation of "quantum unicorns."

Recent announcements signal more than $7 billion in new quantum investments and promotion measures to accelerate social implementation and industrialization.

South Korea & Southeast Asia: Regional Hubs

South Korea is expanding quantum R&D and fabrication as part of its broader semiconductor and digital strategies, including national quantum centres and support for startups.

Singapore is positioning itself as a hub for quantum communications and cloud-based quantum analytics, leveraging A*STAR and university programs. It is also attracting partnerships from global technology firms such as AWS and IBM.

7.8 Policies & Initiatives: India & Middle East

What SMEs need to know: India and the Gulf states are rapidly scaling up from a relatively small base, with generous funding, strong political visibility, and a focus on talent development and industrial pilots - attractive for software-heavy and application-focused SMEs.

India: Liberalization and Private-Sector Growth

India's National Quantum Mission (NQM) (2023 - 2031) has a budget of roughly **US$720M** to build quantum computers, secure quantum networks, advanced sensors, and quantum materials. The mission aims to position India as a global hub, with strong emphasis on quantum workforce development, testbeds, and start-up support. India leverages its large IT and software sector to pursue leadership in quantum software, algorithms, and services.

Middle East: State Investment and Climate Monitoring

Countries such as **Saudi Arabia, UAE, and Qatar** incorporate quantum into innovation-led visions (e.g., Vision 2030, Centennial 2071), focusing on education, research hubs, and partnerships with global players like **IBM** and **Pasqal**.

Saudi Aramco recently deployed the Middle East's first industrial quantum computer, a neutral-atom system built with Pasqal for energy and industrial applications.

7.9 Policies & Initiatives: Canada

Canada: Strategic Investment and Sovereign Leadership in Quantum Technologies

Strategic Framework and Funding:

The National Quantum Strategy (NQS), launched in 2023 with CAD 360 million in dedicated federal funding, is built around three pillars: research, talent and commercialization and three missions: quantum computing, communications, and sensing. In Budget 2025, the federal government committed an **additional CAD 334.5 million** to strengthen and extend quantum-related research, commercialization, and talent development initiatives, reinforcing long-term sovereign capability in quantum technologies.

Implementation is supported by programs at **NRC, NSERC, CIFAR, ISED, and regional innovation agencies**, including:

- Quantum Research and Development Initiative (QRDI)
- Quantum Sensors Challenge Program
- Applied Quantum Computing Challenge Program

Ecosystem and Commercialization

Canada hosts globally recognized institutes such as the Stewart Blusson Quantum Matter Institute, Institute for Quantum Computing (IQC) in Waterloo, Perimeter Institute, SNOLAB and Quantum Valley Investments, which anchor start-up formation and foreign investment. Provincial governments (Ontario, Quebec, British Columbia, Alberta) support quantum hubs, infrastructure, and commercialization programs that align with NQS missions.

Opportunities for Innovation

Climate and resource applications - quantum simulation and sensing for carbon capture, critical minerals, forestry, and energy systems modeling.

Secure communications and cybersecurity - deployment of quantum-safe cryptography and quantum-secured networks across government and critical infrastructure.

Health, pharma, and materials - quantum-enhanced discovery for drugs, diagnostics, and advanced materials, supported by Canada's strong life-sciences and materials research base.

7.10 Mergers, Partnerships and Investments: Overview

Supported by many countries globally with public funding of more than US $55.7 billion, quantum computing, communications, and sensing have become key pillars of advanced technology and national competitiveness. **Global mergers and acquisitions activity** in quantum technology is therefore accelerating as companies look to make the most of strategic funding. A notable example is IonQ's announcement of the US $1.8 billion acquisition of semiconductor foundry SkyWater Technology, aimed at integrating chip manufacturing capabilities into its quantum stack and underpinning its broader hardware and software ambitions. This is the latest in a spree of acquisitions from IonQ. A detailed list of mergers and acquisitions is provided in Appendix C.

Strategic partnerships and commercial agreements are also proliferating beyond pure M&A. D-Wave Quantum secured enterprise contracts including a $20 million system sale to Florida Atlantic University and a $10 million enterprise quantum access agreement with a Fortune 100 firm reflecting emerging demand for real-world deployments and collaborative R&D. Likewise, government-industry partnerships remain critical to bridging research and commercialization, with federal agencies and national labs working closely with corporate actors to accelerate innovation.

Venture capital and institutional investments into quantum startups continue to grow, even as the sector remains a small fraction of broader tech funding. In 2024, publicly announced venture investments into quantum computing firms reached approximately $1.6 billion, with broader reports highlighting global deal value surpassing $1 billion in for the first time and continued strong funding into communications and sensing segments. Key financings include QuEra's $230 million Series B backing from NVentures (NVIDIA's venture capital arm) and Google and Europe's IQM Quantum Computers raising US $300 million in a Series B round, among the largest in the region's quantum ecosystem.

Governments also play a pivotal role in shaping partnerships and investment landscapes. National and regional funds from the European Union's Next Generation funds backing Nu Quantum's Spanish expansion to multilateral alliances on quantum research underscore the strategic importance attributed to quantum technologies worldwide. These public investments often complement private capital, incentivizing joint ventures and cross-border cooperation that aim to maintain competitive advantage amid global tech rivalries.

7.11 Mergers, Partnerships and Investments

Regional Highlights (USA)

United States

The U.S. leads global quantum investment, combining federal R&D with venture and corporate funding. Since the 2018 National Quantum Initiative Act, over US$3B in public investment has supported national labs and centers such as Q-NEXT and Quantum Systems Accelerator (QSA). This funding has mainly strengthened research capability, workforce development, and infrastructure, rather than driving near-term commercial products.

Private investment is flowing into the U.S. quantum sector, but it is unevenly distributed. Venture funding has backed firms including IonQ, Rigetti, Infleqtion, and Atom Computing with roughly 70% of private capital concentrated in quantum hardware. Leading companies have collectively raised over US$1.5 billion, much of it enabled by public listings and elevated valuations, particularly for IonQ and D-Wave. These valuations reflect long-term expectations and have supported aggressive spending and acquisition despite limited current revenues.

Software-focused companies have followed a different path. QC has attracted modest, mid-stage funding, while Zapata raised venture funding earlier before going public and later restructuring. Cybersecurity and sensing firms such as Qrypt and Rydberg show steadier, incremental growth shaped largely by government and defence demand.

Geographically, California, Maryland, and Colorado lead due to venture density, defence ties, and strong university research, while Illinois and Massachusetts remain important for quantum materials and quantum–AI integration.

Key Highlights:

- Strategic consolidation defines the U.S. market. Major deals like Honeywell-Cambridge Quantum (Quantinuum), Infleqtion-Super.tech, and IonQ's acquisitions of Oxford Ionics, Lightsynq Technologies, Capella Space, and Vector Atomic reflect efforts to build integrated technology stacks. Partnerships among federal agencies, national labs, hyperscalers (IBM, Google, Microsoft, AWS), universities, and long-term investors continue to position the U.S. as a globally coordinated yet still pre-commercial quantum innovation hub.

7.12 Mergers, Partnerships and Investments

Regional Highlights (Europe)

Europe

Europe's quantum financing framework blends public programs, national investment funds, and specialized venture capital, further reinforced by strong corporate participation.

France and Germany continue to lead the region. In France, Alice&Bob raised €100 million (Bpifrance, EIC Fund) to advance cat-qubit hardware, while Quandela and Pasqal expanded their photonic and neutral-atom platforms. In **Germany**, planqc secured €20 million in federal support, and HQS Quantum Simulations and Pixel Photonics received funding from EIC and SPRIND innovation programs.

The **United Kingdom** has emerged as a European commercialization hub: Oxford Quantum Circuits raised US $100 million, and **Quantum Motion** closed a £42 million round backed by Bosch and British Patient Capital.

The **Nordic countries and the Netherlands** have developed niche strengths in sensing, cryogenics, and quantum communications technologies, led by Bluefors, QphoX, and Q*Bird underscoring Europe's growing hardware depth and technical diversity.

Key Highlights:

- Recent **merger and acquisition activity** highlights both intra-European consolidation and U.S. strategic expansion. Bluefors strengthened its cryogenics portfolio through the 2023 **acquisitions** of Cryomech and Rockgate, while Muquans merged with iXblue in 2021 to create a European leader in photonics and quantum sensing. These transactions consolidate critical IP, distribution channels, and engineering expertise, but also raise questions about Europe's long-term control over its strategic technologies.
- **Partnerships** remain the defining strength of Europe's quantum ecosystem. Pasqal & IBM, Quantistry & IQM, and Riverlane & Zurich Instruments collaborations are advancing hardware - software integration, while Q*Bird & Eurofiber and Telefónica & IBM strengthen quantum communications infrastructure. EU-level programs such as EuroHPC and Qu-Pilot further align public procurement with industrial scale-up, translating R&D progress into deployable capacity.

7.13 Mergers, Partnerships and Investments

Regional Highlights (Asia & the Middle East)

Asia

Asia's quantum ecosystem combines state-led investment with corporate venture participation, forming one of the world's most diversified regional landscapes.

Singapore exemplifies **government–industry alignment** through the National Research Foundation (NRF) and A*STAR, highlighted by Atomionics' US$12.7M pre-Series A to advance quantum sensing.

Israel has become a magnet for global investors, with Classiq raising US$110M from HSBC and Samsung, and Quantum Machines securing capital from Intel, Qualcomm, and Samsung NEXT.

China remains predominantly state-driven: in 2024, QuantumCTek received CNY 1.78B from China Telecom Quantum Information Technology Group.

On the other hand, **India and Japan** are emerging innovation hubs. India's BosonQ Psi raised US$4.8M to expand simulation technologies, while Japan's NanoQT and Socionext continue to strengthen national capabilities in photonics and quantum semiconductors.

Key Highlights:

- Although merger activity across Asia remains limited, it is increasingly strategic in nature. Japan's OXIDE Corporation acquired Israel's Raicol Crystals for US$25M, securing critical photonics IP, while MUFG Bank took an 18% stake in Groovenauts in 2023 to expand its quantum software exposure. More commonly, Asian quantum companies scale through public listings, Notably, Horizon Quantum Computing's SPAC merger on the U.S. market in 2024 marked a key milestone in global expansion.
- Partnerships continue to drive regional momentum. Quantum Machines joined the IBM Q Network, integrating Israeli control technologies into global infrastructure; Socionext collaborates with Google Quantum AI on next-generation semiconductor controllers; and Xanadu partners with NanoQT and QunaSys in Japan to advance photonic computing and algorithmic co-development. China's QuantumCTek anchors national deployment of quantum key distribution (QKD) networks, while Singapore and India focus on applied collaborations in sensing, simulation, and quantum materials.

7.14 Mergers, Partnerships and Investments: Canada

Over the past five years, Canada's quantum sector has grown rapidly, supported by public funding and rising global strategic interest. Early momentum was driven by federal and provincial programs such as the National Quantum Strategy (CA$360M, 2022), BDC Capital, Investissement Québec, and Ontario's Innovation Growth Fund, which emphasized research translation and early-stage company formation.

Since 2023, foreign strategic and corporate investors have become increasingly active. Examples include Quantonation (France) and Verve Ventures (Switzerland) backing Nord Quantique, and Microsoft and AWS participating in funding rounds for Photonic Inc. and Xanadu respectively.

Funding Trends

Canadian quantum capital is concentrated in hardware-heavy companies, including major rounds such as Photonic's US $100M investment and significant non-dilutive awards under **Canadian Quantum Champions Program** to Xanadu, Photonic, Nord Quantique and Anyon Systems.
By contrast, software and quantum-secure communications examples such as softwareQ and Quantropi appear to raise smaller amounts and frequently leverage government grants and collaborative contracts, consistent with the broader global pattern.

British Columbia and Quebec host active quantum ecosystems supported by both private investment and public programs. For instance, in Quebec, the DistriQ - Quantum Innovation Zone in Sherbrooke attracts companies and talent to shared labs and prototyping facilities, along with federal funding as part of the National Quantum Strategy. Ontario remains a key cluster for quantum startups, with firms such as Toronto-based Xanadu and various software ventures operating alongside strong academic research hubs like the University of Waterloo.

Major Deals:

- Pasqal's 2025 acquisition of AEPONYX, and IonQ's 2023 purchase of Entangled Networks reflect global interest in Canadian IP and talent. Domestic deals like AI/ML Innovations' acquisition of Quantum Sciences aim to integrate AI and quantum sensing.
- Partnerships remain Canada's engine of growth. Universities (Waterloo IQC, Sherbrooke, UBC) collaborate with startups on prototypes; big tech alliances accelerate commercialization; and government consortia (DistriQ, NRC programs) tie it together. Canada's ecosystem thrives on collaboration rather than scale, turning research excellence into applied innovation.

Appendix

Appendix A: Project Scope, Methodology & Assumptions

Project Objective

This study provides a comprehensive landscape analysis of the Quantum Technologies sector with specific emphasis on technologies relating to Quantum Computing, Communications, Sensing, Applications, and Materials. The scope of the project was shaped through iterative consultations and feedback from **Quantum Algorithms Institute (QAI).**

The primary objective is to examine key trends in Quantum Technologies, including:

- The distribution of patented technologies across quantum sub-domains
- Global and regional patent filing trends
- Identification of leading corporate, academic, and institutional players
- Market evolution and policy-driven developments influencing innovation and commercialization

Scope and Coverage

- **Geographical Focus:** Global in scope, with particular attention to developments in Canada, including domestic innovation activity, institutional participation, and international positioning.
- **Patent Data Coverage:** Patent analysis considers filings with a **filing date from 2013 onward**, enabling long-term trend assessment while capturing recent acceleration in quantum innovation.
- **Market Research Window:** Market and ecosystem analysis covers the period from **January 1, 2020, to the present**, reflecting recent investment cycles, policy initiatives, and commercialization activity.

Assumptions and Limitations

- Patent counts for 2024–2025 may be underestimated due to publication delays.
- Patents are classified using a semi-automated tagging approach, combining keyword searches with IPC and CPC classifications.
- Findings reflect data available at the time of analysis and may evolve as additional patent filings are published or reclassified.
- The term “patent” is used throughout the report as a collective reference to granted patents and published patent applications, unless stated otherwise.

Appendix A: Project Scope, Methodology & Assumptions (continued)

Project Methodology

- One representative member per patent family is considered for analysis. A patent family is a collection of patent applications and granted patents filed in various countries, all linked by a common priority application, that cover the same or similar technical content.
- Patent and market insights are derived from trusted databases, including Questel Orbit, Espacenet.com, Google patents, PatSeer, and Tracxn.
- Tagging decisions are informed by review of patent titles, abstracts, and claims, with emphasis on independent claims where deeper technical clarification is required.
- Technology classification in this study is non-exclusive. A single patent may be mapped to multiple quantum technology categories where the claimed invention addresses more than one technical domain or application area. This approach reflects the interdisciplinary nature of quantum innovation and avoids artificially constraining patents to a single category, which could obscure convergence trends and cross-cutting technologies.
- Machine translation is used for non-English patents when no English-language family members are available, to ensure comprehensive coverage.

Integration of Expert Analysis and AI Tools

This report was developed using a combination of in-house research, input from external experts, patent data provided by specialized service providers, and advanced AI tools.

- **Expert Analysis**
  Our team analyzed patent data, market trends, and competitive activity, supported by insights from external analysts and subject matter experts. This combined approach strengthens the accuracy, depth, and relevance of the findings.
- **AI-Assisted Drafting and Insight Support**
  We used advanced language tools (including OpenAI's ChatGPT enterprise version) to help draft, organize, and improve the written sections of the report. In some cases, we also used AI tools to assist with generating insights or shaping conclusions, **always carefully reviewed and verified** by our team before inclusion.
- **Thorough Review and Validation**
  All sections of this report were reviewed, verified, and finalized by experienced professionals to ensure that all insights, conclusions, and recommendations reflect sound judgment, accurate data, and clear analysis.

TABLE OF CONTENTS

Appendix B: Technology Taxonomy: Quantum Computing

Quantum Technologies

1. Quantum Computing

Quantum Hardware/ Qubit technologies (5,369)

- **Superconducting Qubits (879)**
- **Trapped ion Qubits (76)**
- **Neutral atom Qubits (510)**
  - Analog Quantum Computing (e.g. Quera) (160)
  - Gate-Based (Digital) Quantum Computing (377)
- **Photonic Qubits (351)**
  - Qubit-Based (295)
  - CV-Based (57)
- **Silicon Spin/Silicon Quantum Dots (2,499)**
- **Atomic Vapours (348)**
- **Topological Qubits (102)**
- **Nitrogen Vacancy Centers (403)**
- **Quantum Annealing (495)**

Quantum Software (3,084)

- **Quantum Algorithms (1,933)**
  - Algebraic and Number Theoretic Algorithms (124)
  - Oracular (196)
  - Optimization, Numerics, & Machine Learning (1,462)
  - Approximation and Simulation (312)
  - Shor's Algorithm (140)
- **Quantum Compilers (480)**
- **Quantum Debuggers (818)**

Quantum Control Systems (12,704)

- Control Electronics (1,968)
- Qubit Calibration (501)
- Quantum Gates (3,993)
- Decoherence Mitigation (62)
- Quantum Measurement (9,234)

Fundamental Principles (20,359)

- **Quantum Superposition (12,815)**
  - Qubits (8,726)
  - Quantum States (8,140)
- **Quantum Entanglement (1,262)**
  - Entangled Pairs (775)
  - Non-Locality (137)
  - Bell States (505)
- **Quantum Interference (557)**
  - Phase Coherence (247)
  - Quantum Gates (310)
- **Quantum Tunneling (7,408)**
  - Tunneling Phenomena (1,605)
  - Quantum Barriers (6,068)
  - Tunneling Effects in Devices (345)

Quantum Error Correction (2,014)

- Error Correction Techniques (H/W) (898)
- Fault Tolerant Quantum Computing (400)
- Surface Codes (1,455)

Quantum Error Mitigation (58)

- Zero-Noise Extrapolation (6)
- Probabilistic Error Cancellation (12)
- Dynamic Decoupling (38)
- Twirled readout error extinction (TREX) (0)
- Pauli Twirling/Randomized Compiling (7)

Quantum Infrastructure (16,747)

- **Quantum Hardware Infrastructure (1,465)**
  - Cryogenic Systems/Cryogenic Cooling (239)
  - Vacuum Systems (0)
  - Quantum Chip Fabrication (727)
  - Qubit Control Electronics (534)
- **Quantum Software Infrastructure (1,576)**
  - Quantum Development Environments (234)
  - Quantum Cloud Services (1,234)
  - Quantum Middleware (169)
  - Quantum Operating Systems (151)
  - Quantum Resource Management Platform (18)
- **Quantum device Fabrication (14,510)**
  - Semiconductor Fabrication (3,154)
  - Photonic Chip Fabrication (110)
  - Ion Trap Manufacturing (34)
  - Quantum Dot Fabrication (11,618)

TABLE OF CONTENTS

Appendix B: Technology Taxonomy: Quantum Communications

Quantum Technologies

Quantum Communications

Quantum Cryptography/Quantum-Safe Encryption (3,198)

- **Quantum Key Distribution (565)**
  - Quantum Secure Direct Communication (163)
  - Quantum Secret Sharing (121)
  - Quantum Key Agreement (264)
  - Quantum Authentication (31)
- **Post-Quantum Cryptography (740)**
- **Quantum Random Number Generation (1,335)**
- **Secure Multi-party Computation (43)**
- **Cryptographic Hash Functions (1,020)**

Quantum Networking (3,771)

- Quantum Repeaters (163)
- Quantum Routers (285)
- Entanglement Swapping (85)
- Quantum Network Topologies (99)
- Quantum Transmitters (890)
- Quantum Receivers (869)
- Quantum Fiberoptics (2,158)

Quantum Communication Protocols (404)

- BB84 Protocol (309)
- E91 Protocol (32)
- Device-Independent QKD (97)
- Quantum Teleportation Protocols (4)

Quantum Communication Hardware (1,380)

- Quantum Transceivers (87)
- Quantum Amplifiers (244)
- Quantum Signal Processors (805)
- Quantum Communication Chips (268)

Appendix B: Technology Taxonomy: Quantum Sensing & Measurement

Quantum Technologies

Quantum Sensing & Measurement

Quantum Metrology (1,952)

- **Atomic Clocks (159)**
- **Quantum Gravimeters (75)**
- **Quantum Magnetometers (1,027)**
  - Superconducting Quantum Interference Devices (891)
  - Fluxgate Magnetometers (36)
  - Optically Pumped Magnetometers (42)
  - Hall Effect Magnetometers (28)
  - Lorentz Force Magnetometers (1)
  - Atomic Magnetometers (89)
  - Electron Spin Resonance (ESR) Magnetometers (13)
  - Nuclear Magnetic Resonance (NMR) Magnetometers (12)
  - Bose-Einstein Condensate (BEC) Magnetometers (0)
  - Helium Magnetometers (4)
  - Magneto-optical Trap (MOT) Magnetometers (7)
- **Quantum Thermometers (516)**
- **Quantum Electric Field Sensors (88)**
- **Quantum Accelerometers (93)**
- **Quantum Rotation Sensors (141)**

Quantum Imaging (1,105)

- **Quantum Microscopy (692)**
- **Quantum Lithography (392)**
- **Quantum Interference Imaging (28)**
- **Quantum Ghost Imaging (12)**

Technologies (4,799)

- **Quantum Environmental Sensors (2,228)**
  - Quantum Biosensors (452)
  - Quantum Chemical Sensors (324)
  - Quantum Mechanical Sensors (300)
  - Quantum Radiation Sensors (1,214)
- **Quantum Acoustic Sensors** (147)
- **Quantum Interferometers (1,009)**
- **Quantum Imaging Sensor (2,293)**
- **Quantum Electromagnetic Sensors (520)**

Quantum Image Processing (39)

- **Flexible Representation of Quantum Images (FRQI) (29)**
- **N-qubit Encoded Quantum Representation (NEQR) (13)**
- **Quantum Probability Image Encoding (QPIE) (0)**
- **Quantum Hadamard Edge Detection (QHED) (0)**

Appendix B: Technology Taxonomy: Quantum Applications & Quantum Materials

Quantum Technologies

Quantum Applications

- **Quantum Simulation (481)**
  - Chemical Simulations (299)
  - Material Science Simulations (190)
  - Biological Simulations (59)
  - High Energy Physics Simulations (0)
- **Quantum Optimization (2,120)**
  - Quantum-Inspired Algorithms (1,264)
  - Portfolio Optimization (49)
  - Supply Chain Optimization (42)
  - Scheduling Optimization (209)
  - Traffic Optimization (103)
  - Electrical/Telecom Grid Optimization (192)
  - Chemistry/Biology Based Optimization (499)
- **Quantum Machine Learning (964)**
  - Quantum Neural Networks (801)
  - Quantum Support Vector Machines (117)
  - Quantum Reinforcement Learning (68)
  - Hybrid Quantum-Classical Machine Learning (12)

- **Quantum Cryptographic Applications (7,887)**
- **Healthcare and Pharmaceuticals (3,599)**
- **Finance (292)**
- **Logistics and Supply Chain (128)**
- **Energy (7,099)**
- **Artificial Intelligence (7,218)**
- **Chemistry and Material Science (28,757)**
- **Communication (25,139)**
- **Defence (90)**
- **Transportation (2,028)**
- **Display and Lighting Devices (18,696)**
- **Environment (1,507)**
- **Manufacturing (126)**

Quantum Materials

- Quantum Dots (41,292)
- Quantum Well (13,272)
- Topological Insulators (2,704)
- Superconductors (709)
- Complex Magnets (186)
- Graphene (5,187)
- Ultra-cold Atoms (100)
- Multiferroics (24)

TABLE OF CONTENTS

Appendix C: Taxonomy Definitions (Quantum Computing)

QUANTUM COMPUTING

Quantum computing is a type of computation that utilizes the principles of quantum mechanics to process information. Unlike classical computers, which use bits as the smallest unit of data (0s and 1s), quantum computers use qubits. Qubits can exist in multiple states simultaneously due to a property called superposition, allowing quantum computers to perform many calculations at once. This enables quantum computers to solve complex problems more efficiently than classical computers.

TAXONOMY NODES	DEFINITION
Quantum Hardware/ Qubit Technologies	Quantum hardware refers to the physical systems and technologies that make quantum computing possible. This includes the devices and components that manipulate quantum bits, or qubits, which are the fundamental building blocks of quantum information processing.
Superconducting Qubits	Superconducting qubits are quantum bits based on superconducting circuits, where the principles of superconductivity are used to create and control quantum states.
Trapped Ion Qubits	Trapped ion qubits are based on ions that are confined using electromagnetic fields and manipulated using laser pulses to perform quantum operations.
Neutral Atom Qubits	Neutral atom qubits are a type of quantum bit (qubit) used in quantum computing that is based on neutral atoms, which are atoms that have no net electric charge. These qubits leverage the unique properties of neutral atoms to perform quantum information processing.
Analog Quantum Computing (e.g. Quera)	Analog quantum computing utilizes continuous variables and quantum states of neutral atom qubits to perform computations by simulating quantum systems directly
Gate-Based (Digital) Quantum Computing	Digital quantum computing employs discrete quantum gates and circuits to manipulate neutral atom qubits
Photonic Qubits	Photonic qubits are a type of quantum bit (qubit) that uses photons, or light particles, to represent and manipulate quantum information. Photonic qubits exploit the quantum properties of light, including superposition and entanglement, making them a compelling option for various quantum computing and communications applications.
Qubit-Based	Qubit-based photonic systems use discrete quantum states of photons to represent qubits for quantum computations.
CV-Based	CV-based systems encode information in the continuous degrees of freedom of light, such as amplitude and phase.
Silicon Spin/Silicon Quantum Dots	Silicon spin qubits utilize the intrinsic spins of electrons in silicon to encode quantum information
Atomic Vapours	Atomic vapours utilize the quantum states of atoms for qubit implementation

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Topological Qubits	Topological qubits are based on anyons—special particles in certain quantum states that encode information in their topological properties, which are robust against local disturbances.
Nitrogen Vacancy Centers	Nitrogen vacancy (NV) centers in diamond serve as stable qubits with long coherence times, enabling applications in quantum sensing and quantum computing.
Quantum Annealing	Quantum annealing is a quantum optimization technique that uses quantum fluctuations to find the minimum of a cost function, effectively solving complex combinatorial problems.
Quantum Software	Quantum software refers to programs and applications designed to run on quantum computers, harnessing the principles of quantum mechanics to perform calculations and solve problems. Unlike classical software, which is built for traditional binary computers, quantum software is developed specifically to leverage the unique capabilities of quantum computing, such as superposition, entanglement, and quantum interference.
Quantum Algorithms	Quantum algorithms are specialized computational procedures designed to run on quantum computers. They leverage the principles of quantum mechanics, such as superposition, entanglement, and quantum interference, to solve problems more efficiently than classical algorithms.
Algebraic and Number Theoretic Algorithms	These quantum algorithms leverage quantum parallelism to efficiently solve problems in algebra and number theory, such as factoring large integers and computing discrete logarithms, which have significant implications for cryptography.
Oracular	Oracular algorithms utilize a quantum oracle to provide solutions to specific problems, allowing for the exploration of complex decision-making processes and enhancing computational efficiency in various applications.
Optimization, Numerics, & Machine Learning	Quantum algorithms in optimization, numerics, and machine learning aim to improve the efficiency of solving optimization problems, performing numerical simulations, and enhancing machine learning models through quantum speedup.
Approximation and Simulation	These algorithms focus on approximating solutions to complex problems and simulating quantum systems, enabling more efficient computations in fields like quantum chemistry and materials science.
Shor's Algorithm	Shor's Algorithm is a quantum algorithm designed to efficiently factorize large composite numbers.
Quantum Compilers	Quantum compilers translate high-level quantum algorithms into low-level instructions that can be executed on quantum hardware, optimizing for gate efficiency and error mitigation to enhance performance.
Quantum Debuggers	Quantum debuggers are tools designed to identify and correct errors in quantum programs, providing insights into the behavior of quantum circuits and ensuring the reliability of quantum computations.

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Quantum Control Systems	Quantum control systems refer to the techniques and mechanisms used to manipulate and stabilize quantum systems for various applications in quantum computing, quantum communications, and quantum sensing. These systems are essential for achieving precise control over quantum states, enabling the performance of complex operations on qubits and other quantum systems.
Control Electronics	Control electronics are essential for generating and managing the precise signals required to manipulate qubits and execute quantum operations in quantum computing systems.
Qubit Calibration	Qubit calibration involves fine-tuning the parameters of qubits to ensure optimal performance and accuracy in quantum operations, minimizing errors and enhancing coherence times.
Quantum Gates	Quantum gates are the fundamental building blocks of quantum circuits, enabling the manipulation of qubit states through unitary operations to perform quantum computations.
Decoherence Mitigation	Decoherence mitigation techniques aim to reduce the effects of environmental noise on qubits, preserving quantum information and extending coherence times for reliable computation.
Quantum Measurement	Quantum measurement is the process of extracting information from qubits, collapsing their quantum states to classical outcomes, and is crucial for reading the results of quantum computations.
Fundamental Principles	The Fundamental Principles of Quantum Computing include quantum superposition, entanglement, and interference, allowing qubits to exist in multiple states, be interconnected, and enhance solution accuracy, enabling powerful and complex computations beyond classical capabilities.
Quantum Superposition	Quantum superposition is a fundamental principle of quantum mechanics that describes how a quantum system can exist in multiple states or configurations simultaneously until it is measured or observed. This principle contrasts sharply with classical physics, where objects exist in a definite state at any given time.
Qubits	Qubits are the fundamental units of quantum information that can exist in a superposition of states, allowing them to represent multiple values simultaneously, which is key to the power of quantum computing.
Quantum States (e.g. Bose-Einstein Condensate (BEC))	Quantum states describe the condition of a qubit or a system of qubits, encapsulating the probabilities of different outcomes and enabling superposition, where a qubit can be in a combination of both 0 and 1 states at the same time.
Quantum Compilers	Quantum compilers translate high-level quantum algorithms into low-level instructions that can be executed on quantum hardware, optimizing for gate efficiency and error mitigation to enhance performance.
Quantum Debuggers	Quantum debuggers are tools designed to identify and correct errors in quantum programs, providing insights into the behavior of quantum circuits and ensuring the reliability of quantum computations.

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Quantum Control Systems	Quantum control systems refer to the techniques and mechanisms used to manipulate and stabilize quantum systems for various applications in quantum computing, quantum communications, and quantum sensing. These systems are essential for achieving precise control over quantum states, enabling the performance of complex operations on qubits and other quantum systems.
Control Electronics	Control electronics are essential for generating and managing the precise signals required to manipulate qubits and execute quantum operations in quantum computing systems.
Qubit Calibration	Qubit calibration involves fine-tuning the parameters of qubits to ensure optimal performance and accuracy in quantum operations, minimizing errors and enhancing coherence times.
Quantum Gates	Quantum gates are the fundamental building blocks of quantum circuits, enabling the manipulation of qubit states through unitary operations to perform quantum computations.
Decoherence Mitigation	Decoherence mitigation techniques aim to reduce the effects of environmental noise on qubits, preserving quantum information and extending coherence times for reliable computation.
Quantum Measurement	Quantum measurement is the process of extracting information from qubits, collapsing their quantum states to classical outcomes, and is crucial for reading the results of quantum computations.
Fundamental Principles	The Fundamental Principles of Quantum Computing include quantum superposition, entanglement, and interference, allowing qubits to exist in multiple states, be interconnected, and enhance solution accuracy, enabling powerful and complex computations beyond classical capabilities.
Quantum Superposition	Quantum superposition is a fundamental principle of quantum mechanics that describes how a quantum system can exist in multiple states or configurations simultaneously until it is measured or observed. This principle contrasts sharply with classical physics, where objects exist in a definite state at any given time.
Qubits	Qubits are the fundamental units of quantum information that can exist in a superposition of states, allowing them to represent multiple values simultaneously, which is key to the power of quantum computing.
Quantum States (e.g. Bose-Einstein Condensate (BEC))	Quantum states describe the condition of a qubit or a system of qubits, encapsulating the probabilities of different outcomes and enabling superposition, where a qubit can be in a combination of both 0 and 1 states at the same time.
Quantum Entanglement	Quantum entanglement is a phenomenon in quantum mechanics where two or more particles become interconnected in such a way that the state of one particle instantly influences the state of the other, regardless of the distance between them. This interconnectedness persists even if the entangled particles are separated by vast distances, leading to correlations that cannot be explained by classical physics.
Entangled Pairs	Entangled pairs are pairs of qubits whose quantum states are interdependent, such that the measurement of one qubit instantaneously affects the state of the other, regardless of the distance separating them.

Appendix C: Taxonomy Definitions (Quantum Computing)

TABLE OF CONTENTS

TAXONOMY NODES	DEFINITION
Non-Locality	Non-locality refers to the phenomenon in quantum mechanics where entangled particles exhibit correlations that cannot be explained by classical physics, demonstrating that information can be shared instantaneously across distances.
Bell States	Bell states are specific maximally entangled quantum states of two qubits that serve as fundamental resources for quantum information tasks, such as quantum teleportation and superdense coding, illustrating the unique properties of quantum entanglement.
Quantum Interference	Quantum interference is a phenomenon that occurs when two or more quantum states overlap and combine in a way that either enhances or cancels out the probability amplitudes of those states. This effect is a fundamental aspect of quantum mechanics and is responsible for many of the unique behaviors observed in quantum systems, particularly in wave-like phenomena.
Phase Coherence	Phase coherence refers to the consistent phase relationship between quantum states, which is essential for enabling constructive and destructive interference effects in quantum systems, ultimately influencing the outcomes of quantum computations.
Quantum Gates	Quantum gates manipulate the quantum states of qubits through interference effects, allowing for the creation of superpositions and entanglements that are fundamental to performing quantum algorithms and computations.
Quantum Tunneling	Quantum tunneling is a quantum mechanical phenomenon that occurs when a particle passes through a potential energy barrier that it classically should not be able to overcome due to insufficient energy. This effect is a direct consequence of the principles of quantum mechanics, particularly the wave-like nature of particles.
Tunneling Phenomena	Tunneling phenomena describe the quantum mechanical process where particles can pass through energy barriers that they classically should not be able to surmount, enabling unique behaviors in quantum systems.
Quantum Barriers	Quantum barriers are potential energy barriers that can be penetrated by particles due to quantum tunneling, allowing for the transfer of particles between states that would otherwise be inaccessible.
Tunneling Effects in Devices	Tunneling effects in devices, such as tunnel diodes and quantum dots, exploit quantum tunneling to enable rapid switching and enhanced performance in electronic and quantum computing applications.
Quantum Error Correction	Quantum error correction is an essential component of quantum computing, addressing the challenges posed by errors and decoherence in quantum systems. By enabling the reliable manipulation and storage of quantum information, it plays a vital role in advancing quantum technology and facilitating the development of practical quantum computers.
Error Correction Techniques (H/W)	Error correction techniques in hardware are methods designed to detect and correct errors in quantum computations, ensuring the reliability and accuracy of quantum information processing.
Fault-Tolerant Quantum Computing	Fault-tolerant quantum computing refers to the design of quantum systems that can continue to operate correctly even in the presence of errors, enabling robust and scalable quantum computation.

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Surface Codes	Surface codes are a class of quantum error-correcting codes that utilize a two-dimensional lattice structure to protect quantum information from errors, providing a practical and efficient framework for achieving fault tolerance in quantum computing.
Quantum Error Mitigation	Quantum error mitigation refers to techniques used to reduce the impact of errors in quantum computing systems without requiring full error correction. Unlike quantum error correction, which often involves redundantly encoding data across multiple qubits to correct errors, quantum error mitigation focuses on reducing errors in the output of quantum computations, particularly in near-term quantum devices, where error rates can be significant but may not yet warrant a comprehensive correction scheme.
Zero-Noise Extrapolation	Zero-Noise Extrapolation (ZNE) is a method employed in quantum computing to reduce the impact of noise that affects quantum operations, helping to enhance the precision of the results produced by quantum calculations.
Probabilistic Error Cancellation	Probabilistic Error Cancellation is a method used in quantum computing to enhance the precision of quantum calculations by tackling the errors that arise from noise and defects in quantum processes.
Dynamical Decoupling	Dynamical decoupling is a key technique in quantum technology that preserves quantum state coherence from environmental noise by using strategic control pulses, thereby enhancing the reliability of quantum computations and measurements.
Twirled Readout Error Extinction (TREX)	Twirled Readout Error Extinction (TREX) is an important method in quantum technology aimed at improving the precision of qubit measurements by reducing readout errors through a systematic use of twirling techniques.
Pauli Twirling/Randomized Compiling	Pauli Twirling, or Randomized Compiling, is an effective technique in quantum computing designed to reduce errors and improve the accuracy of quantum operations. By using random sequences of Pauli gates, this method enhances the resilience of quantum computations, leading to the creation of more reliable quantum technologies.
Quantum Infrastructure	Quantum infrastructure refers to the essential physical and technological components required to support the development, deployment, and operation of quantum computing systems and applications. This infrastructure encompasses a range of elements, including hardware, software, networks, and facilities that enable the functioning and scalability of quantum technologies.
Quantum Hardware Infrastructure	Quantum hardware infrastructure refers to the physical and technological systems required to support the development, operation, and maintenance of quantum computing hardware. This infrastructure encompasses a range of components that work together to enable the functioning of quantum devices, facilitating experiments, research, and application development in quantum technology.
Cryogenic Systems/Cryogenic Cooling	Cryogenic systems are essential in quantum hardware infrastructure for maintaining superconducting qubits at ultra-low temperatures, minimizing thermal noise and enabling coherent quantum operations.

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Vacuum Systems	Vacuum systems are critical for quantum hardware infrastructure as they provide a controlled environment that reduces contamination and external interference, ensuring the stability and performance of quantum devices.
Quantum Chip Fabrication	Quantum chip fabrication involves the precise manufacturing processes required to create quantum processors, integrating qubits and control circuitry on a chip to enable scalable quantum computing.
Qubit Control Electronics	Qubit control electronics are vital components in quantum hardware infrastructure that generate and manage the signals used to manipulate qubits, facilitating their operation and interaction in quantum computations.
Quantum Software Infrastructure	Quantum software infrastructure refers to the foundational software systems, tools, and frameworks that support the development, execution, and management of quantum algorithms and applications. This infrastructure is crucial for bridging the gap between quantum hardware and practical applications, enabling users to harness the power of quantum computing effectively.
Quantum Development Environments	Quantum development environments provide tools and frameworks for developers to design, simulate, and test quantum algorithms, facilitating the creation of quantum software.
Quantum Cloud Services	Quantum cloud services offer remote access to quantum computing resources, enabling users to run quantum algorithms on actual quantum hardware without needing to own the infrastructure.
Quantum Middleware	Quantum middleware acts as an intermediary layer that simplifies the interaction between quantum hardware and software applications, providing essential services like error handling and resource management.
Quantum Operating Systems	Quantum operating systems manage the execution of quantum algorithms and the allocation of quantum resources, ensuring efficient operation and coordination of quantum tasks.
Quantum Resource Management Platform	Quantum resource management platforms optimize the allocation and scheduling of quantum computing resources, enhancing the efficiency and performance of quantum applications.

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Quantum Device Fabrication	Quantum device fabrication refers to the processes and techniques used to create physical devices that utilize quantum principles for their operation, such as quantum computers, quantum sensors, and other quantum-based technologies. This field combines advanced materials science, nanofabrication, and quantum engineering to produce devices that can manipulate quantum states for various applications.
Semiconductor Fabrication	Semiconductor fabrication involves the processes used to create semiconductor-based quantum devices, such as qubits, by precisely manipulating materials at the nanoscale to achieve desired electronic properties.
Photonic Chip Fabrication	Photonic chip fabrication focuses on the production of integrated optical devices that utilize photons for quantum information processing, enabling the development of quantum communications and computing technologies.
Ion Trap Manufacturing	Ion trap manufacturing involves creating devices that use electromagnetic fields to confine and manipulate charged particles (ions) for use as qubits in quantum computing, allowing for high-precision quantum operations.
Quantum Dot Fabrication	Quantum dot fabrication is the process of producing nanoscale semiconductor particles that can confine electrons and holes, serving as qubits in quantum computing and enabling applications in quantum optics and photonics.

Appendix C: Taxonomy Definitions (Quantum Communication)

Quantum Communications

Quantum communications is a field of study and application that uses the principles of quantum mechanics to enable secure information transfer between parties. It leverages quantum states to encode and transmit data, making it fundamentally distinct from classical communication methods.

TAXONOMY NODES	DEFINITION
Quantum Cryptography/ Quantum-Safe Encryption	Quantum Cryptography refers to the use of quantum mechanics to secure communications and protect information. It fundamentally enhances the security of cryptographic systems by utilizing the principles of quantum physics, primarily through the use of quantum bits (qubits).
Quantum Key Distribution	Quantum Key Distribution (QKD) is a method used in quantum cryptography to securely share cryptographic keys between two parties, allowing for safe communication over potentially insecure channels. The security of QKD derives from the principles of quantum mechanics rather than mathematical algorithms, making it fundamentally distinct from traditional key distribution methods.
Quantum Secure Direct Communication	Quantum secure direct communications enables the transmission of information directly between parties using quantum states, ensuring that the communication is secure from eavesdropping without the need for a shared key.
Quantum Secret Sharing	Quantum secret sharing is a method that allows a secret to be divided into parts and distributed among multiple parties, ensuring that only a subset of them can reconstruct the secret, enhancing security through quantum principles.
Quantum Key Agreement	Quantum key agreement is a protocol that allows two or more parties to collaboratively generate a shared secret key using quantum mechanics, ensuring that the key remains secure against eavesdropping.
Quantum Authentication	Quantum authentication employs quantum techniques to verify the identity of users or devices, ensuring that only authorized parties can access quantum communications channels and resources, thereby enhancing security.
Post-Quantum Cryptography	Post-quantum cryptography refers to cryptographic algorithms designed to be secure against the potential threats posed by quantum computers, ensuring data protection.
Quantum Random Number Generation	Quantum random number generation utilizes the inherent unpredictability of quantum mechanics to produce truly random numbers, which are essential for secure cryptographic applications.
Secure Multi-Party Computation	Secure multi-party computation enables multiple parties to jointly compute a function over their inputs while keeping those inputs private, utilizing quantum techniques to enhance security and privacy.
Cryptographic Hash Functions	Cryptographic hash functions are algorithms that transform input data into a fixed-size string of characters, providing data integrity and security.

Appendix C: Taxonomy Definitions (Quantum Communications)

TAXONOMY NODES	DEFINITION
Quantum Networking	Quantum networking is a field that focuses on the interconnection of quantum devices and systems, enabling the transmission of quantum information over distances. It leverages the principles of quantum mechanics to create secure communication channels and distribute quantum states, such as qubits, among multiple locations.
Quantum Repeaters	Quantum repeaters are devices that extend the range of quantum communications by enabling the distribution of entanglement over long distances, overcoming the limitations of direct transmission due to loss and decoherence.
Quantum Routers	Quantum routers are specialized devices that direct quantum information through a network, facilitating the efficient routing of quantum states between different nodes in a quantum communications system.
Entanglement Swapping	Entanglement swapping is a process that allows two pairs of entangled particles to share entanglement with each other, enabling the creation of entangled states over longer distances and enhancing quantum communications capabilities.
Quantum Network Topologies	Quantum network topologies refer to the structural arrangements of quantum nodes and connections in a quantum network, influencing the efficiency and robustness of quantum communications protocols.
Quantum Transmitters	Quantum transmitters are devices that encode and send quantum information, such as qubits, over a communication channel, playing a crucial role in quantum networking.
Quantum Receivers	Quantum receivers are systems designed to detect and decode quantum information transmitted over a network, ensuring accurate retrieval of the quantum states sent by transmitters.
Quantum Fiberoptics	Quantum fiberoptics involve the use of optical fibers specifically designed for transmitting quantum information, enabling high-fidelity communication of quantum states over long distances with minimal loss.
Quantum Communications Protocols	Quantum communications protocols are systematic methods or procedures that use quantum mechanics to secure communications and facilitate the transfer of information between parties. These protocols exploit the unique properties of quantum systems, such as superposition and entanglement, to achieve security levels that are unattainable with classical communication methods.
BB84 Protocol	The BB84 protocol is a pioneering quantum key distribution method that uses the principles of quantum mechanics to securely share encryption keys between two parties, ensuring that any eavesdropping can be detected.
E91 Protocol	The E91 protocol allows two parties to generate a shared secret key by measuring entangled particles, providing security through the fundamental properties of quantum mechanics.
Device-Independent QKD	Device-independent quantum key distribution (DI-QKD) enables secure key exchange without trusting the devices used, relying on the observed correlations of quantum states to ensure security against potential device vulnerabilities.

Appendix C: Taxonomy Definitions (Quantum Computing)

TAXONOMY NODES	DEFINITION
Quantum Teleportation Protocols	Quantum teleportation protocols enable the transfer of quantum states from one location to another without physically transmitting the particle itself, utilizing entanglement and classical communication to achieve this process.
Quantum Communications Hardware	Quantum communications hardware refers to the physical devices and systems that facilitate the transmission and processing of quantum information. This hardware is essential for implementing quantum communications protocols and includes various components designed to leverage the properties of quantum mechanics, such as superposition and entanglement.
Quantum Transceivers	Quantum transceivers are devices that both transmit and receive quantum information, facilitating bidirectional communication in quantum networks by encoding and decoding quantum states.
Quantum Amplifiers	Quantum amplifiers are specialized devices that boost the strength of quantum signals without adding significant noise, enhancing the transmission distance and fidelity of quantum communications.
Quantum Signal Processors	Quantum signal processors manipulate quantum information to perform tasks such as filtering, error correction, and signal enhancement, playing a crucial role in the effective transmission and reception of quantum data.
Quantum Communications Chips	Quantum communications chips integrate various quantum components on a single chip, enabling compact and efficient processing of quantum information for applications in quantum networking and communications systems.

Appendix C: Taxonomy Definitions (Quantum Sensing & Measurement)

Quantum Sensing & Measurement

Quantum sensing and measurement refer to techniques that utilize quantum mechanics to achieve highly sensitive measurements beyond the limits of classical sensors. These methods exploit quantum properties, such as superposition and entanglement, to enhance the precision and accuracy of measurements in various fields, including metrology, imaging, and navigation.

TAXONOMY NODES	DEFINITION
Quantum Metrology	Quantum metrology is a branch of science that focuses on the use of quantum mechanics to improve measurement techniques and enhance the precision of measurements. It leverages quantum phenomena, such as superposition and entanglement, to achieve measurement accuracy beyond the limits of classical metrology.
Atomic Clocks	Atomic clocks are highly precise timekeeping devices that use the vibrations of atoms to measure time, serving as the standard for timekeeping and enabling advancements in navigation and telecommunications.
Quantum Gravimeters	Quantum gravimeters measure gravitational acceleration with exceptional precision by utilizing the interference of matter waves, providing valuable data for geophysics and resource exploration.
Quantum Magnetometers	Quantum magnetometers are sensitive instruments that utilize quantum mechanics to measure magnetic fields with high precision. They exploit quantum properties, such as superposition and entanglement, to enhance the sensitivity and accuracy of magnetic field measurements beyond the capabilities of classical magnetometers.
Superconducting Quantum Interference Devices	Superconducting Quantum Interference Devices (SQUIDs) are highly sensitive magnetometers that exploit quantum interference effects in superconducting circuits to measure extremely weak magnetic fields, making them invaluable tools in quantum metrology for applications such as medical imaging, geophysics, and fundamental physics research.
Fluxgate Magnetometers	Fluxgate technology utilizes magnetic materials with hysteresis to detect small changes in magnetic fields, but its sensitivity is offset by the bulkiness and significant power consumption of fluxgate magnetometers, limiting their use in compact devices.
Optically Pumped Magnetometers	Optically pumped magnetometers use an atomic vapor cell and lasers to detect magnetic fields, offering high sensitivity and accuracy, which makes them ideal for scientific research.
Hall Effect Magnetometers	Hall effect magnetometers measure the strength of a magnetic field by detecting the voltage generated across a conductor when positioned perpendicular to the field; while they are compact and energy-efficient, their limited sensitivity makes them suitable primarily for on/off detection applications.

Appendix C: Taxonomy Definitions (Quantum Sensing & Measurement)

TAXONOMY NODES	DEFINITION
Lorentz Force Magnetometers	Lorentz Force Magnetometers are instruments that detect magnetic fields by utilizing the Lorentz force principle, which outlines the force acting on a charged particle as it moves through a magnetic field.
Atomic Magnetometers	Atomic Magnetometers are sensitive devices that detect magnetic fields by utilizing the magnetic properties of atomic states and the interaction of light with atoms, enabling them to measure extremely weak magnetic fields down to the picoTesla level.
Electron Spin Resonance (ESR) Magnetometers	Electron Spin Resonance (ESR) Magnetometers are specialized devices that measure magnetic fields by utilizing electron spin resonance, making them highly sensitive to changes in magnetic fields, particularly in materials with unpaired electrons like free radicals and transition metal complexes.
Nuclear Magnetic Resonance (NMR) Magnetometers	Nuclear Magnetic Resonance (NMR) Magnetometers are sophisticated devices that measure magnetic fields using the principles of nuclear magnetic resonance, primarily to analyze the magnetic properties of atomic nuclei, especially hydrogen nuclei (protons) in chemistry and medicine.
Bose-Einstein Condensate (BEC) Magnetometers	Bose-Einstein Condensate (BEC) Magnetometers are quantum sensors that measure magnetic fields with high precision by exploiting the collective behavior of bosons cooled to near absolute zero, which allows them to occupy the same quantum state.
Helium Magnetometers	Helium Magnetometers are specialized devices that measure magnetic fields using the unique properties of helium gas and its isotopes, leveraging the spin of helium nuclei to detect very weak magnetic fields with high sensitivity.
Magneto-optical Trap (MOT) Magnetometers	Magneto-Optical Trap (MOT) Magnetometers are specialized devices that use magneto-optical trapping with magnetic fields and laser light to cool and manipulate atoms for accurate magnetic field measurements.
Quantum Thermometers	Quantum thermometers leverage quantum properties to achieve high sensitivity and accuracy in temperature measurements, enabling precise thermal monitoring in various scientific and industrial applications.
Quantum Electric Field Sensors	Quantum electric field sensors detect electric fields with high sensitivity by exploiting quantum phenomena, allowing for advanced measurements in fields such as electromagnetism and materials science.
Quantum Accelerometers	Quantum accelerometers measure acceleration with high precision using quantum interference effects, providing critical data for navigation, geophysical studies, and inertial sensing applications.
Quantum Rotation Sensors	Quantum rotation sensors, or quantum gyroscopes, utilize quantum mechanics to measure angular rotation with high accuracy, enhancing navigation systems and applications in aerospace and robotics.

Appendix C: Taxonomy Definitions (Quantum Sensing & Measurement)

TAXONOMY NODES	DEFINITION
Quantum Imaging	Quantum imaging is a field of study and technology that leverages the principles of quantum mechanics to improve the capture and analysis of images beyond the capabilities of classical imaging techniques. It utilizes quantum phenomena, such as superposition, entanglement, and quantum interference, to enhance imaging resolution, sensitivity, and measurement precision.
Quantum Microscopy	Quantum microscopy employs quantum effects to achieve high-resolution imaging at the nanoscale, allowing for detailed observation of biological and material structures.
Quantum Lithography	Quantum lithography utilizes quantum interference to create patterns with resolutions surpassing classical limits, enhancing the fabrication of micro and nanoscale devices.
Quantum Interference Imaging	Quantum interference imaging harnesses the wave-like properties of quantum particles to improve image contrast and resolution, enabling detailed imaging of complex systems.
Quantum Ghost Imaging	Quantum ghost imaging uses entangled photons to reconstruct images, allowing for high-resolution imaging in low-light conditions and the detection of weak signals.
Quantum Sensing Technologies	Quantum sensing technologies are advanced measurement systems that exploit the principles of quantum mechanics to achieve unprecedented sensitivity and precision in measuring physical quantities. These technologies leverage quantum phenomena such as superposition, entanglement, and quantum interference to enhance the capabilities of sensors beyond what is achievable with classical systems.
Quantum Environmental Sensors	Quantum environmental sensors are advanced measurement devices that utilize the principles of quantum mechanics to assess and monitor environmental conditions with high precision and sensitivity. These sensors can detect various physical quantities, such as temperature, humidity, pressure, magnetic fields, and pollutants, often at levels of sensitivity that exceed traditional sensing technologies.
Quantum Biosensors	Quantum biosensors utilize quantum properties to detect biological molecules with high sensitivity and specificity, enabling advancements in medical diagnostics and environmental monitoring.
Quantum Chemical Sensors	Quantum chemical sensors leverage quantum mechanics to identify and quantify chemical substances at extremely low concentrations, enhancing capabilities in environmental analysis and safety monitoring.
Quantum Mechanical Sensors	Quantum mechanical sensors exploit quantum phenomena to measure physical quantities such as force, pressure, and displacement with exceptional precision, applicable in various scientific and industrial fields.
Quantum Radiation Sensors	Quantum radiation sensors detect and measure various forms of radiation using quantum effects, providing critical data for safety, environmental monitoring, and scientific research.

Appendix C: Taxonomy Definitions (Quantum Sensing & Measurement)

TAXONOMY NODES	DEFINITION
Quantum Acoustic Sensors	Quantum Acoustic Sensors are sophisticated instruments that employ quantum mechanics to identify and quantify acoustic waves, which are vibrations that propagate through different media, including solids, liquids, and gases.
Quantum Interferometers	Quantum Interferometers are advanced devices that leverage quantum interference to precisely measure various physical properties. By utilizing the wave-like behavior of particles, such as photons and atoms, they create interference patterns that reveal valuable information about the measured quantities, including phase shifts and displacements.
Quantum Imaging Sensor	Quantum Imaging Sensors are sophisticated devices that leverage quantum mechanics to capture and process images with greater sensitivity and accuracy than classical systems. By utilizing phenomena such as superposition and entanglement, these sensors enhance the quality and effectiveness of various imaging applications.
Quantum Electromagnetic Sensors	Quantum Electromagnetic Sensors are sophisticated devices that harness quantum mechanics to precisely detect and measure electromagnetic fields and radiation. By utilizing unique quantum properties like superposition and entanglement, these sensors achieve enhanced sensitivity and resolution compared to traditional sensors.
Quantum Image Processing	Quantum image processing is an emerging field that combines the principles of quantum computing and quantum mechanics with techniques for processing and analyzing images. It aims to leverage the unique capabilities of quantum systems to improve image processing tasks, potentially offering advantages over classical image processing methods in terms of speed, efficiency, and the ability to handle complex data structures.
Flexible Representation of Quantum Images (FRQI)	The FRQI state is a method for converting classical images into quantum images on a quantum computer, represented in a normalized format. It encapsulates both the color and position information of image pixels, allowing for efficient preparation of images that can be processed with quantum image processing algorithms.
N-qubit Encoded Quantum Representation (NEQR)	The NEQR representation encodes the grayscale values of each pixel in a sequence of qubits, in contrast to the FRQI method, which captures probability amplitudes. This representation utilizes the entanglement of color and position information to effectively represent the image.
Quantum Probability Image Encoding (QPIE)	Quantum Probability Image Encoding (QPIE) is an innovative method in quantum image processing that represents classical images in a quantum state using probability-based encoding.
Quantum Hadamard Edge Detection (QHED)	Quantum Hadamard Edge Detection (QHED) is a specialized technique in quantum image processing that employs the Hadamard transform to enhance edge detection capabilities.

Appendix C: Taxonomy Definitions (Quantum applications)

Quantum Applications

Quantum applications refer to the practical uses of quantum computing, quantum communications, quantum cryptography, and other quantum technologies across various fields and industries. These applications leverage the unique properties of quantum mechanics, such as superposition, entanglement, and quantum interference, to solve complex problems, enhance performance, and enable new technologies

TAXONOMY NODES	DEFINITION
Quantum Simulation	Quantum simulation is a computational technique that uses quantum systems to model and study the behavior of other quantum systems. This approach takes advantage of the unique properties of quantum mechanics to simulate complex quantum interactions and phenomena that are difficult or impossible to model using classical computers.
Chemical Simulations	Quantum simulations in chemistry enable the accurate modeling of molecular interactions and reactions at the quantum level, providing insights into chemical properties and processes that are difficult to achieve with classical methods.
Material Science Simulations	Quantum simulations in material science allow researchers to investigate the properties and behaviors of materials at the atomic scale, facilitating the design of new materials with tailored characteristics.
Biological Simulations	Quantum simulations in biology help model complex biological systems and processes, such as protein folding and molecular interactions, enhancing our understanding of biological functions and drug interactions.
High Energy Physics Simulations	Quantum simulations in high energy physics provide tools to explore fundamental particles and forces, enabling the study of phenomena such as quantum field theories and the behavior of matter under extreme conditions.
Quantum Optimization	Quantum optimization refers to the application of quantum computing techniques to solve optimization problems more efficiently than classical methods. Optimization involves finding the best solution from a set of possible solutions, which can be particularly challenging for complex problems where traditional algorithms may require an exponential amount of time to find the optimal solution.
Quantum-Inspired Algorithms	Quantum-inspired algorithms leverage principles from quantum computing to solve complex optimization problems more efficiently than classical algorithms.
Portfolio Optimization	Portfolio management aims to maximize returns while minimizing risk by efficiently analyzing large datasets and complex financial models.
Supply Chain Optimization	Quantum optimization methods enhance supply chain management by improving logistics, inventory control, and resource allocation, leading to reduced costs and increased efficiency.

Appendix C: (Quantum Applications)

TAXONOMY NODES	DEFINITION
Scheduling Optimization	Scheduling optimization aims to efficiently allocate resources and time slots in various contexts, such as workforce management and project planning, to minimize delays and maximize productivity.
Traffic Optimization	Traffic optimization improves flow, reduces congestion, and enhances route planning, leading to more efficient transportation networks.
Electrical/Telecom Grid Optimization	Quantum optimization methods are used to enhance the performance and reliability of electrical and telecommunications grids by optimizing resource distribution and load balancing.
Chemistry/Biology Based Optimization	Chemistry and biology optimization focuses on optimizing molecular structures and interactions, aiding in drug discovery and the design of new materials through efficient computational methods.
Quantum Machine Learning	Quantum Machine Learning (QML) is a multidisciplinary field that combines quantum computing and machine learning to enhance the capabilities of traditional machine learning algorithms. QML seeks to exploit the unique features of quantum mechanics, such as superposition and entanglement, to process and analyze data in ways that classical machine learning cannot achieve.
Quantum Neural Networks	Quantum neural networks utilize quantum computing principles to enhance the capabilities of traditional neural networks, potentially enabling faster training and improved performance on complex tasks.
Quantum Support Vector Machines	Quantum support vector machines leverage quantum algorithms to optimize the classification of data, offering potential speedups in training and accuracy compared to classical support vector machines.
Quantum Reinforcement Learning	Quantum reinforcement learning combines quantum computing with reinforcement learning techniques, aiming to improve decision-making processes and learning efficiency in dynamic environments.
Hybrid Quantum-Classical Machine Learning	Hybrid quantum-classical machine learning integrates quantum algorithms with classical machine learning methods, capitalizing on the strengths of both approaches to tackle complex problems more effectively.

Appendix C: (Quantum Applications)

TAXONOMY NODES	DEFINITION
Quantum Cryptographic Applications	Quantum technologies provide secure communications methods through quantum key distribution and other cryptographic protocols, ensuring data integrity and confidentiality.
Healthcare and Pharmaceuticals (e.g., Drug Discovery, Imaging, Protein Folding)	Quantum technologies enhance drug discovery, improve imaging techniques, and facilitate protein folding analysis, leading to breakthroughs in medical treatments and diagnostics.
Finance (e.g., Risk Analysis, portfolio optimization, fraud detection)	Quantum technologies optimize financial processes through advanced algorithms for risk analysis, portfolio optimization, and fraud detection, improving decision-making and efficiency.
Logistics and Supply Chain (e.g., Route Optimization, Inventory Management, Supply Chain Resilience)	Quantum technologies improve logistics and supply chain management by enabling efficient route optimization, inventory control, and resilience against disruptions.
Energy (e.g., Battery Research, Grid Management, Renewable Energy Optimization)	Quantum technologies advance energy solutions through enhanced battery research, improved grid management, and optimization of renewable energy systems for greater efficiency.
Artificial Intelligence (e.g., Quantum ML, Neural Networks)	Quantum technologies enhance artificial intelligence capabilities by enabling faster data processing and more powerful machine learning algorithms, such as quantum neural networks.
Chemistry and Material Science (e.g., Quantum Chemistry Simulations, Quantum Photonics)	Quantum technologies facilitate accurate quantum chemistry simulations and advancements in quantum photonics, aiding in the design and discovery of new materials.
Communication (e.g., Cryptography, Quantum Networks, Quantum Teleportation)	Quantum technologies enhance communications security through quantum cryptography, support the development of quantum networks, and enable quantum teleportation for secure data transfer.

Appendix C: (Quantum Applications)

TAXONOMY NODES	DEFINITION
Defence (e.g., Quantum Radar, Quantum Sensors)	Quantum technologies improve defence capabilities with advanced quantum radar and sensors, enhancing detection, surveillance, and situational awareness.
Transportation (e.g., Autonomous Vehicles, Traffic Management, Aviation Optimization)	Quantum technologies optimize transportation systems through improved algorithms for autonomous vehicles, traffic management, and aviation operations, enhancing efficiency and safety.
Display and Lighting Devices (e.g., LED, QLED, TV, Laser Diodes)	Quantum technologies contribute to the development of advanced display and lighting devices, such as QLEDs and laser diodes, improving energy efficiency and visual performance.
Environment (e.g., Climate Modeling, Pollution Control, Water Management)	Quantum technologies aid environmental monitoring and research through enhanced climate modeling, pollution control strategies, and efficient water management systems.
Manufacturing (e.g., Quantum Enhanced Quality Control)	Quantum technologies enhance manufacturing processes through improved quality control measures, leading to greater product consistency and reduced waste.

Appendix C: (Quantum materials)

Quantum materials

Quantum materials are materials that exhibit unique properties and behaviors arising from quantum mechanical effects. These materials are of significant interest in condensed matter physics, material science, and quantum technology because their quantum characteristics can lead to novel phenomena and potential applications in various fields, including electronics, computing, and sensing.

TAXONOMY NODES	DEFINITION
Quantum Dots	Quantum dots are nanoscale semiconductor particles that confine charge carriers in all three dimensions, leading to discrete energy levels and size-dependent optical and electronic properties for use in displays, photodetectors, and solar cells.
Quantum Well	Quantum wells are thin layers of semiconductor material that confine charge carriers in one dimension, leading to quantized energy levels and enhanced electronic and optical properties for use in lasers and photodetectors.
Topological Insulators	Topological insulators are materials that conduct electricity on their surfaces while remaining insulating in their bulk, exhibiting unique electronic properties that could lead to advancements in quantum computing and spintronics.
Superconductors	Superconductors are materials that can conduct electricity without resistance below a certain temperature, enabling applications in powerful magnets, quantum computing, and lossless power transmission.
Complex Magnets	Complex magnets exhibit intricate magnetic behaviors and interactions, which can lead to novel phenomena such as spintronic effects and are of interest for advanced magnetic materials and devices.
Graphene	Graphene is a single layer of carbon atoms arranged in a two-dimensional lattice, known for its exceptional electrical, thermal, and mechanical properties, making it a promising material for various applications, including electronics and materials science.
Ultra-Cold Atoms	Ultra-Cold Atoms are atoms cooled to temperatures near absolute zero, usually between microkelvins and nanokelvins. At these extremely low temperatures, the thermal motion of the atoms is greatly diminished, enabling them to display quantum mechanical behaviors on a macroscopic scale.
Multiferroics	Multiferroics are a class of materials that exhibit more than one primary ferroic property simultaneously, most commonly ferroelectricity, ferromagnetism, and/or ferroelasticity. In quantum materials, multiferroics have garnered significant interest due to their unique coupling between these properties at the atomic level and their potential applications in advanced technologies.

Appendix D: Key Mergers and Acquisitions (1/4)

TABLE OF CONTENTS

Serial Number	Primary Entity	Secondary Entity	Year	Details of Acquired/Partnered Entity
1	IonQ	SkyWater	2026	In January 2026, IonQ announced that it will acquire US-based semiconductor foundry, SkyWater technology for approx. US$1.8B. (Source)
2	D-Wave	Quantum Circuits Inc.	2026	D-Wave completed acquisition of Quantum Circuits Inc. (Source)
3	Atlantic Quantum	Google Quantum AI	2025	Atlantic Quantum team is joining Google, which is acquired by Google Quantum AI in October 2025. (Source)
4	Pasqal	Aeponyx	2025	Pasqal announced the acquisition of AEPONYX, a Canadian company in photonic integrated circuits (PICs) in June 2025. (Source)
5	Google Quantum AI	Atlantic Quantum	2025	Google Quantum acquired MIT-founded startup, Atlantic Quantum (Source)
6	IonQ	Vector Atomic	2025	In October 2025, IonQ announced successful completion of its acquisition of California based quantum sensing company, Vector Atomic. (Source)

Appendix D: Key Mergers and Acquisitions (2/4)

Serial Number	Primary Entity	Secondary Entity	Year	Details of Acquired/Partnered Entity
7	IonQ	Lightsynq	2025	In June 2025, IonQ announced successful completion of its acquisition of Boston-based based quantum memory and photonic interconnects company, Lightsynq. (Source)
8	IonQ	ID Quantique	2025	In February 2025, IonQ announced an agreement to acquire a controlling stake in ID Quantique. (Source)
9	IonQ	Oxford Ionics	2025	IonQ completed acquisition of Oxford Ionics, Accelerating Path to Pioneering Breakthroughs in Quantum Computing. (Source)
10	IonQ	Qubitekk, Inc.	2025	IonQ Completes Acquisition of Qubitekk in 2025 (Source)
11	Hewlett Packard Enterprise	IQM Quantum Computers	2024	IQM Quantum Computers Collaborates With Hewlett Packard Enterprise And Demonstrates Quantum-HPC Integration. (Source)
12	SandboxAQ	Good Chemistry	2024	In January 2024, SandboxAQ completed acquisition of Canadian computational chemistry company, Good Chemistry. (Source)

Appendix D: Key Mergers and Acquisitions (3/4)

Serial Number	Primary Entity	Secondary Entity	Year	Details of Acquired/Partnered Entity
13	IBM Quantum	HashiCorp	2024	In 2024 IBM Quantum acquired HashiCorp, the deal value is 6.4 million. (Source)
14	Fincantieri	Leonardo	2024	In May 2024 Italy's Fincantieri has acquired the submarine unit of defence group Leonardo in a deal valuing the asset at up to €415mn. (Source)
15	MAGELLAN BLOCKS	Groovenauts	2023	MUFG Bank has acquired approximately 18% of Groovenauts' outstanding shares. (Source)
16	INTEL Labs	Tower Semiconductor	2023	In 2023, it acquired Tower Semiconductor and the deal later terminated which was 5.4 million dollars. (Source)
17	Nanosys Technology	Shoei Chemical	2023	In 2023, Shoei Chemical has announced the asset purchase Nanosys. (Source)
18	Bluefors	Rockgate	2023	Finnish manufacturer of cryogenic measurement systems, Bluefors acquired its Japanese distributor of cryogenic equipment, Rockgate in May 2023. (Source)

Appendix D: Key Mergers and Acquisitions (4/4)

Serial Number	Primary Entity	Secondary Entity	Year	Details of Acquired/Partnered Entity
19	Bluefors	Cryomech	2023	Finnish manufacturer of cryogenic measurement systems, Bluefors acquired a Syracuse, US based cryocooler company, Cryomech in March 2023. (Source)
20	Raicol Quantum Crystals	OXIDE Corporation	2023	OXIDE Corporation agreed to acquire Raicol Crystals Ltd. from Raicol Holdings Ltd for $25.1 million, in 2023 (Source)
21	Arqit	Centricus Acquisition Corp	2021	2021 $1.4 billion business combination with Centricus Acquisition Corp., which took the company public on Nasdaq under the ticker ARQQ. (Source)
22	Eviden	Visual BI Solutions, Nimbix, Cloudreach	2021	In 2021, it acquired Visual BI Solutions and Nimbix; In 2022 acquired Cloudreach. (Source)
23	iXblue	Muquans	2021	In 2021, Muquans was merged into iXblue's photonics quantum unit. (Source)

IAC CAI

Innovation Asset Collective
67 Erb Street West
Waterloo, ON
N2L 6C2

www.ipcollective.ca

IAC is funded by the
Government of Canada

Canada

QUANTUM ALGORITHMS INSTITUTE

Quantum Algorithms Institute
295 – 13540 102 Avenue
Surrey, BC
V3T 5X3

www.qai.ca