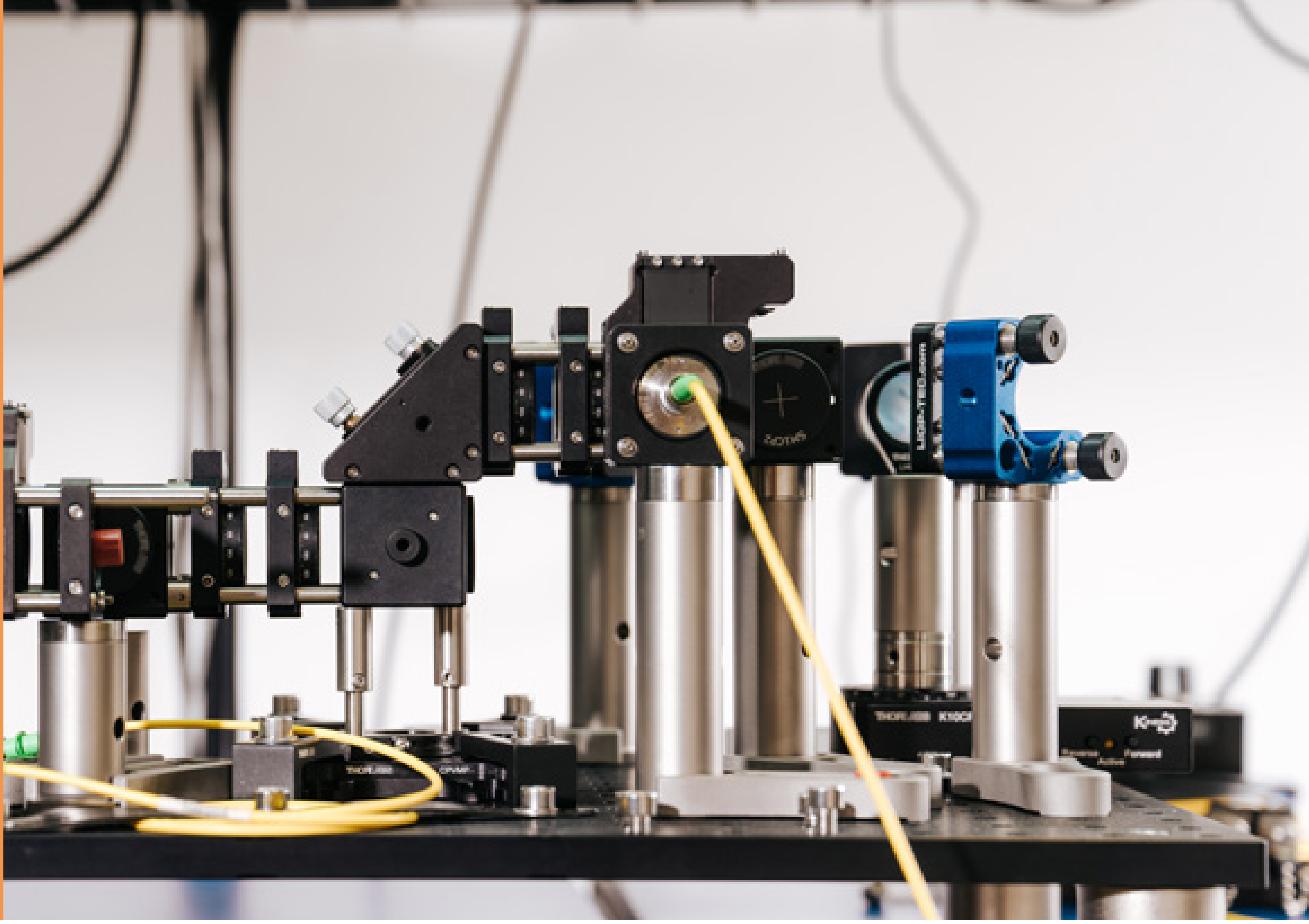

Venturing into Quantum Technology in the Netherlands

Deep Tech Fund, Invest-NL
October 2023

Deep Tech

Courtesy of Qblox

Contents

Introduction

Dear readers,

In an era where the boundaries of technological progress are constantly being pushed, Quantum Technology is increasingly seen as one of the great promises of tomorrow. Quantum is one of the Key Enabling Technologies that the Deep Tech Fund of Invest-NL focuses on.

As an investor in technology pioneers, we have embraced the uncharted territory of Quantum and have started to explore the possibilities that Quantum offer.

We began with what seemed like a simple consideration: What is the role of Quantum Technology in the future of the Netherlands? As a Deep Tech Fund, we aim to provide Venture Capital to Dutch companies dedicated to developing essential technologies for transformational societal challenges. In this regard, the long-term importance of Quantum is still challenging for many to grasp, and it sometimes carries a certain mystique reminiscent of the stories of Jules Verne.

To understand the potential and relevance of Quantum Technology, we embarked on research, partly because Quantum was also a new field for Invest-NL. We mapped the Dutch Quantum ecosystem and formulated an investment strategy for it. Our emphasis is on creating impact for the Dutch Quantum ecosystem. More specifically, it's to further stimulate and expand the strong academic position, that the Netherlands holds in several Quantum domains, into relevant Dutch Quantum enterprises.

With this report, we aim to achieve the following: We want to provide investors with insights into the Quantum technology landscape in the Netherlands, highlighting the current state of affairs and promising developments. We share our investment vision regarding Quantum Technology to encourage private investors to join us.

And perhaps equally important, as the saying goes: "unknown makes unloved." By informing private and public (co-)investors about Quantum Technology in the Netherlands, we hope to at least remove the "unknown" and thereby lower the barrier to considering investments in this technology. While Quantum Technology may appear as an unknown horizon, it represents a world of opportunities with unprecedented possibilities.

We look forward to a future in which Quantum technology plays a significant role for the benefit of our society and economy. We invite you to embark on this journey with us and discover this new dimension of technological advancement.

Best regards,

Gert-Jan Vaessen
Fund manager Deep Tech Fund Invest-NL

27 organizations from the Dutch Quantum ecosystem interviewed for this study

(non exhaustive) list of parties interviewed:

Quantum companies:
Delft Circuits
Single Quantum
LioniX
Leiden Cryogenics
Qphox
Quix
Onnes Technologies
Qbird
Orange Quantum Systems
Qblox
Quantware
FermioniQ
PasQal / Qu&Co
Photon

Investors:
ForwardOne
Innovation Industries
IMECXpand
Quantonation

Organizations:
Quantum Delta
QuTech
TNO
TTO Delft (Enterprises)
TTO Leiden
TTO Twente / OostNL
TTO Eindhoven (Gate)
QAL
AQA

The Invest-NL Deep Tech Fonds (DTF) aims to strengthen the Deep Tech ecosystem in the Netherlands by co-investing with private investors in early stage start-ups. Within the scope of Deep Tech is also Quantum Technology, one of The Netherlands' Key Enabling Technologies. In this context', a study has be conducted to map out the Quantum Technology ecosystem in The Netherlands and formulate a Quantum Technology investment strategy for the Deep Tech Fonds.

The DTF is open for investment proposals from Quantum Technology Start-ups[4] in the Netherlands, as most Quantum start-ups so far fit well within the DTF's scope. The DTF will co-invest with other investors in those start-ups that are assessed as sufficiently attractive. It assesses the Quantum start-ups by a.o.:

- business case, team, financials and other factors that are part of its standard DD and assessment process;
- (global) competitive position, to what extent it is (globally) state-of-the-art and their ability to maintain or improve its competitive position;

In addition, the DTF assesses the start-up on "**impact**" on the eco system and/or "**criticality**" in the Quantum value chain (i.e. for a: Quantum computer, scalable QKD/Quantum Internet network, Sensing solutions), noting that typically:

- full stack[1,2] players in Computing and Communications typically score relatively high on both;
- components/equipment companies that are critical **for scaling of** Computing/ Communication/Sensing solutions, score high on criticality;
- scoring of players in Sensing depend on the Sensing application;
- factors that are considered in assessing impact are a.o.: interdependency of other players in the eco system, revenue, overall size and structure, business case.

The **Quantum start-ups** in The Netherlands on the radar (14 current + 4 that have not yet started up), that are in scope, require an estimated **total of €1-2B**[3] in capital to get to their intended market and profitability, of which **±50%** for **full-stack players**.
€150-300M of this would be needed in **the next 1-1.5 yrs**.

15-20 additional Quantum start-ups are expected in the coming 2 years (of which 70% Computing, 30% Communications; 50% components/equipment, 30% hardware/full-stack, 20% app software/services). Presently 1 Full-stack Quantum computing player in The Netherlands (QuiX) and 1 Full-stack player in Quantum Communications (Qbird).

Main perceived **eco-system bottlenecks** for companies to innovate & grow more quickly:
Capacity at the facilities (facility capabilities are cited to be sufficient and in some cases among the best globally), e.g.:

1) clean room (most companies),
2) test set-ups (a.o. cryo fridges),
3) nano-fab/foundry,
4) photonics chip foundry – as stated by all parties interviewed, and;

- Funding – as stated by start-ups and QuantumDelta (some TTOs[5] note it has become easier in early stage because of recent focus on Quantum Technology), and;
- Management/Executives/Entrepreneurs to complement the academic founders – as stated by TTOs, VCs, QuantumDelta.

Eco-system strengths:

- Upstream capabilities are very strong: expertise for addressing tech roadmaps' bottlenecks is in-house or within 2.5 hour drive in almost all cases (with few though notable exceptions), and
- Recruiting technical people – not perceived to be an issue for most relevant disciplines (yet), though expected to change as ratio Quantum companies : Quantum academia is increasing.

1. Full-stack player in Quantum Computing refers to a company that makes and sells fully functional Quantum Computers, at least up to the control software (not necessarily application software and services). Among Full-stack players, there are different degrees of vertical integration, i.e. the number of (sub)systems a company makes itself vs. sourcing. Though they might source some of its critical components, in this report a Full-stack player refers to a company that ultimately sells a fully functioning Quantum Computer.
2. Full-stack player in Quantum Communication is a company that makes and sells (a) scalable QKD/Quantum communication network(s) that can also be hooked up to a PC (QKD) or Quantum Computer (Quantum communication/internet).
3. Multiple investors/experts active in Deep Tech have indicated that approximately 1.5-2 times more capital is typically required than estimated by the companies themselves (in this case a total of €700-1100M) to complete a plan/ roadmap over the given timelines.
4. (Fundamental) Quantum start-ups in this report fall into 2 categories. 1) Quantum Computing/ Communication/Sensing companies: their products/services rely on exploitation Quantum mechanical properties/dynamics to outperform "classical" counterparts (that don't exploit these properties/dynamics) in terms functionality and/or performance. 2) companies that make components for category 1) which are A) critical in the roadmaps and performance of category 1's technology, and; B) do not have an alternative technological solution (yet).
5. Technology Transfer Office – the office within a University responsible for the University's Intellectual Property, almost always involved in the formation of start-ups spinning out of the University.

Invest-NL's Deep Tech Fonds fouces on Deep Tech early stage start-ups in The Netherlands (NL)

"Deep Tech companies apply a **novel scientific and engineering breakthrough** for the first time in the form of a product. This means there is technical risk in getting the idea to actually work.

Deep Tech starts with an extended R&D phase and involves a higher share of technical staff compared to conventional ventures. Deep Tech also often involves the development of hardware and/or IP which are more **capital and time intensive**.

Once technical risk is overcome, there is additional risk in proving market demand for that product. If market demand is proven, Deep Tech startups have **stronger defensibility from competition thanks to technology barriers**, instead of having to rely on network effects and market lock-up. **What' s Deep Tech today is not necessarily Deep Tech tomorrow**. Once the technology or product is no longer novel and as the company scales, what was once Deep Tech becomes regular tech. "

Invest-NL serves as the Dutch National Promotional Institution. As a leading impact investor, its core mission is to facilitate financing for ventures that may initially seem challenging to fund. By working in collaboration with diverse stakeholders, including financiers, investors, and development specialists from both the public and private sectors, Invest-NL actively tackles significant societal challenges. These encompass the transition towards a carbon-neutral and circular economy, promoting affordable and accessible healthcare and fostering advancements in deep tech. Established in 2020, Invest-NL operates as a privately-held entity, financed through public funds, with the Dutch Ministry of Finance as its sole shareholder.

Invest-NL's Deep Tech Fonds was established in 2022 by Invest-NL and the Dutch Ministry of Economic Affairs & Climate to bolster the fundability of the Deep Tech companies in the Netherlands.

Many Quantum Technology companies fit the mandate of Deep Tech Fonds because of their capital requirement and timeline to reach their intended market.
All companies are subject to the Deep Tech Fonds technical Due Diligance assessment process.

Main characteristics DTF

Fund	
Legal entity	Invest-NL Capital N.V.
Fund size	EUR 250 mln.
Limited partners	Ministry Economic Affairs (EZK) Invest-NL Capital
Duration	>15 years
Investment Strategy	
Co-investment	Pari passu with private (lead) investor
Instruments	Mainly equity
Company stage	Multi-stage (start-/scale-up), TRL 3-9
Scope	Disruptive key enabling technologies (R&D intensive, capital intensive and scientific base)
Ticket size	EUR 1 mln. – EUR 15 mln. per round Max. EUR 37,5 mln. per company
Portfolio	12 – 15 companies
Ownership	<50% (no majority)
Geography	The Netherlands
Impact	FTE, R&D and contribution to Dutch innovation ecosystem/economy

Invest-NL's Deep Tech Fonds fouces on Deep Tech early stage start-ups in The Netherlands (NL)

The DTF team / Investment team

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The DTF team / Investment Committee

Frits van Hout
IC Chairman
Current role: SB chair/member of several companies

Hans Büthker
IC Member
Current role: CEO Neways Electronics

Eline van Beest
IC member
Current role: CEO Hybridize and Venture Partner Thuja Capital

Aruna Subramanian
IC Member
Current role: Managing Director SABIC and IC member Energie Transitie Fonds

Steven Tan
IC Member
Current role: Founder/Director Nascent Ventures

Results as of October 2023

€32 mln.
Invested

jobs
>480 FTE

2.75x
Investment
Multiplier

>260 patents

Portfolio as of October 2023

Portfolio as of October 2023

What's the market, applications and how is it different from current solutions?

Quantum Technology, here's what you need to know

Courtesy of QuiX Quantum

Quantum Technology market expected to grow up to $106B by 2040, over 3 domains

The outlook and potential impact of Quantum Technology in various industries is continuously evolving as technological progress is made, the understanding of how to address remaining technological bottlenecks is growing and devices are reaching market.
The midpoint of the market estimates by 2035-2040 of organizations such as IDC, BCG, McKinsey, Quantum insider and market research firms is currently in the range of 50-70B (the estimates of 3 of these organizations are shown in the table).

McKinsey latest high estimate is a total of $106B by 2040, over 3 Quantum Technology domains: Computing, Communication and Sensing – of which Computing is the biggest with ±90% of the market. Estimates on the Quantum communication market in 2040 differ most widely between in relative terms, from 1B to 20B/yr.

How realistic are these estimates and their timelines?

The main driver of the Quantum Technology market growth is expected to be Quantum Computing (which was estimated at €0.4-0.5B in 2022). Until 10 years ago, it was often predicted that a practical quantum computer was “20-30 years” away, now it’s 7-8 years. The old estimate reflected the lack of a realistic R&D roadmap from the basic demonstrations to a viable product.

This situation drastically changed over the last decade. Currently, the roadmaps do exist: leading research groups and computing companies confidently plan the development of quantum computers of 1000-qubit size computers by this or next year. Some companies with new technological approaches predict error corrected computers at relevant scale before 2030.

In addition, because of developments in Quantum software and collaborations with Industry partners, a better understanding has arisen around the potential value and market.

Publish Yr,	Published by	now	2030	2035	2040
2021	IDC		9		
2021	BCG - low	0.5	1	15	90
2021	BCG - high	1	2	30	170
2023	McKinsey - low				9
2023	McKinsey - high				93

Several consultancy and market research firms have published estimates. While McKinsey’s has the greatest range, most see an R&D market ramping up from €0.4-0.5M in 2022 to a couple of €B in 2030 and and tens of €B in 2035 and beyond. Source: McKinsey Quantum Technology Monitor April 2023, BCG, Arthur D Little, IDC, Quantum Insider

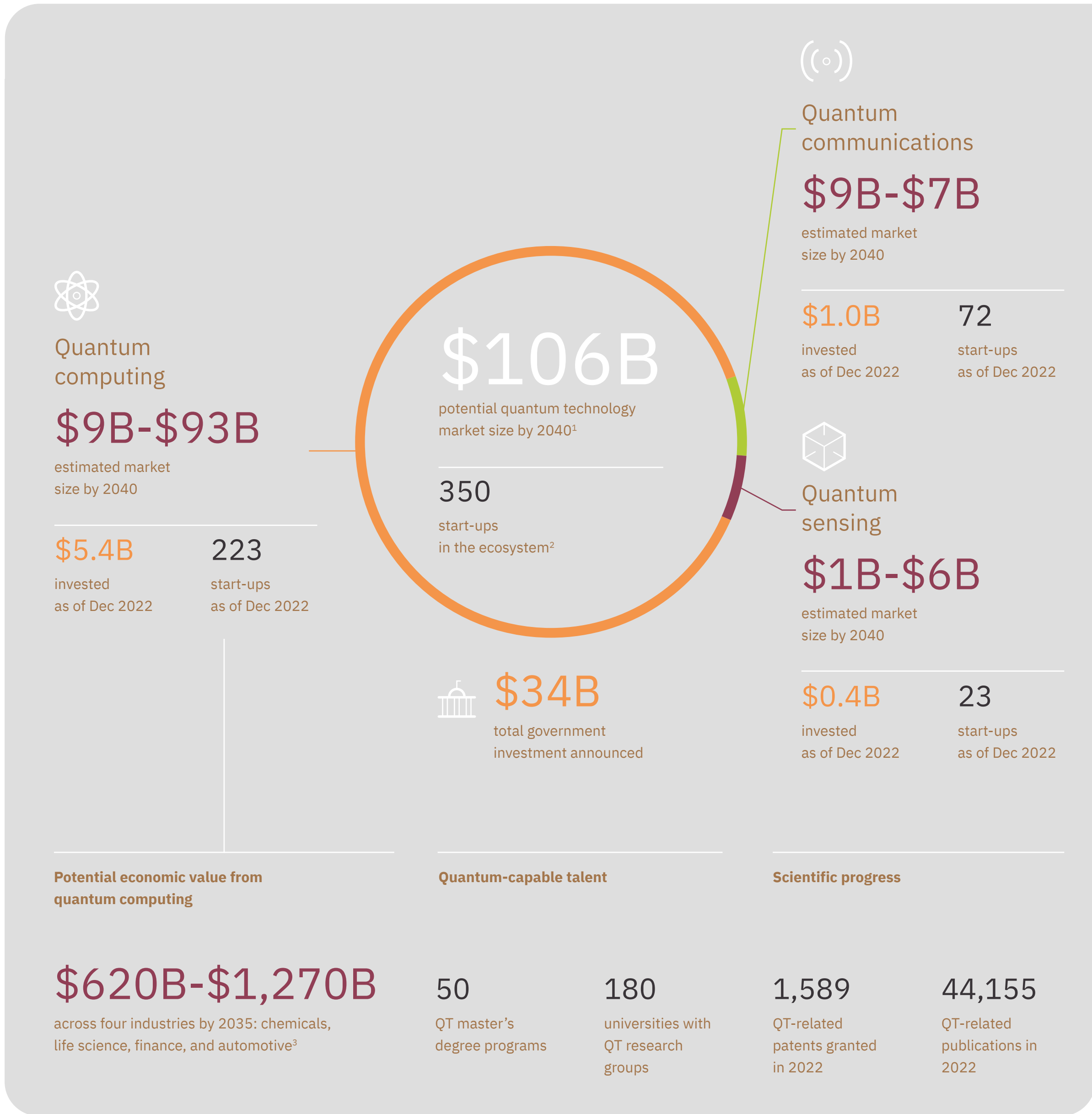


Chart from McKinsey’s Quantum Technology Monitor April 2023,” showing the global Quantum Technology eco-system in 2023. Its estimate for the global Quantum Technology market is up to 106B by 2040 over 3 domains: Quantum Computing, Communication and Sensing. This is based on a value gain of 620-12790B for its users.

Quantum Computing solves certain problems with speed and complexity beyond reach of super computers

What's the value of Quantum Computing?

The value of Quantum Computing lies in the ability to solve certain problems much more quickly (up to exponentially more quickly) and/or are too complex for traditional (super) computers.
This is enabled with the use of "quantum algorithms". What a traditional supercomputer might take 1000 years, a Quantum computer could do, with quantum algorithms, in a few seconds.

The main classes of these problems are:
- Simulation, e.g.: how a certain pharmaceutical molecule would interact with its target;
- Optimization (of parameters), e.g.: optimizing parameters in order to make structural car part stronger and more durable while lowering its weight and production cost;

- RSA (Cryptogrpahy), i.e.: hacking most of current data encryption (of e.g. your email or banking) much faster. Currently it would take several super computers 1000s to 1'000'000s of years. A large-scale Quantum computer can hack exponentially faster, completing the same process in seconds. As a side note, the notion above has given rise to new ways of encrypting "classical" data that cannot be hacked by Quantum Computers, so call Post Quantum Cryptography (PQC). Assuming Quantum computers will start to proliferate around 2030-2032, PQC is expected to become widely implemented before then. Most are looking towards the US National Institute of Standards and Technology (NIST) for new PQC encryption standards in the next 1-3 years and expect them to then be rolled out.
- Machine learning / Artificial Intelligence (AI), i.e.; many AI and machine learning tasks involve "complex optimization problems", simulations, matrix operations and exceptionally big & high dimensional data sets – some of this problem solving can be accelerated (up to exponentially faster) by Quantum Computers, making AI much faster and capable;

It is expected that Quantum computing will be most disruptive in Finance (e.g.: portfolio optimization, buying/selling decisions),
Life Science (drastic improvement drug development process), Chemicals (drastic improvement development process of new compounds, materials & processes) and Travel,Transport&Logistics (optimization supply chains and transportation schedules, like the "Salesman problem") and bring tremendous efficiency & effectiveness gain in AI (faster, capable) and Engineering (optimization designs, enabling new functionality).

Source: McKinsey's "Quantum Technology monitor, April 2023", Quantum Insider, expert interviews

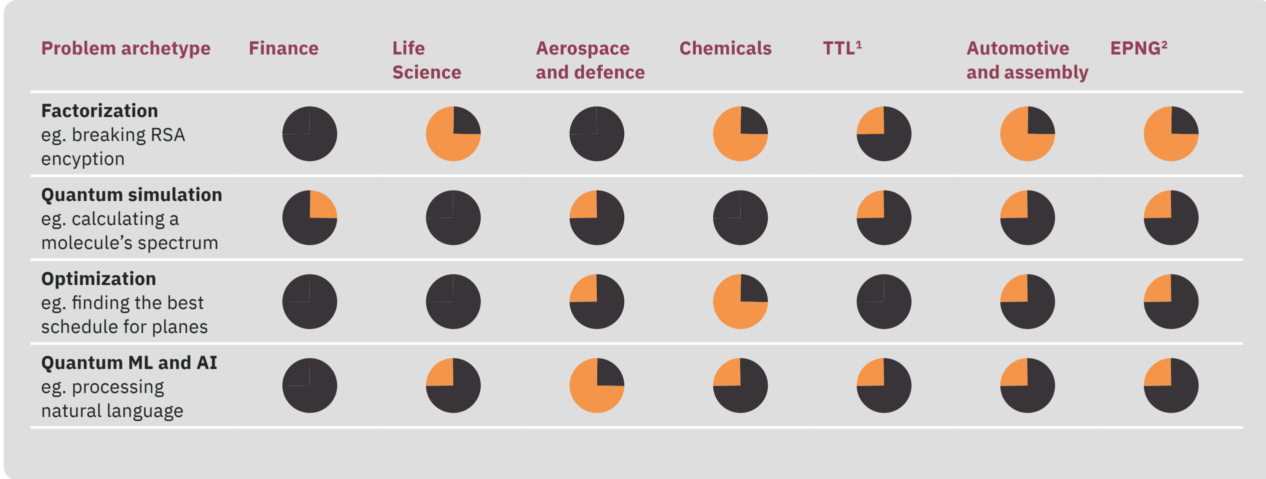


Chart from McKinsey's Quantum Technology Monitor April 2023 showing the Quantum Computer's various calculation classes (where it has significant speed-up versus traditional super computers) and its impact on several industries.

Most disruptive impact is expected in Finance, Life sciences, Aerospace & defense and Travel, Transport & Logistics (TTL). Like the advancements made possible by traditional computing, harnassing the capabilities of Quantum Computing in these industries will become increasingly key for the ability to remain competitive.

Qubits, superposition, entanglement and quantum gates are key concepts in Quantum Computing

So, what is the difference between a Quantum Computer and a traditional “classical” computer?

The most notable differences are:

- In traditional computers information is stored on and handled by “bits” which can have the value 0 or 1. Quantum computers however work with “quantum bits” (known as “qubits”). These can be 0 and 1, each with a certain probability, simultaneously. This is called “superposition”. Superposition enables that exponentially more information can be stored on qubits than on (traditional) bits.

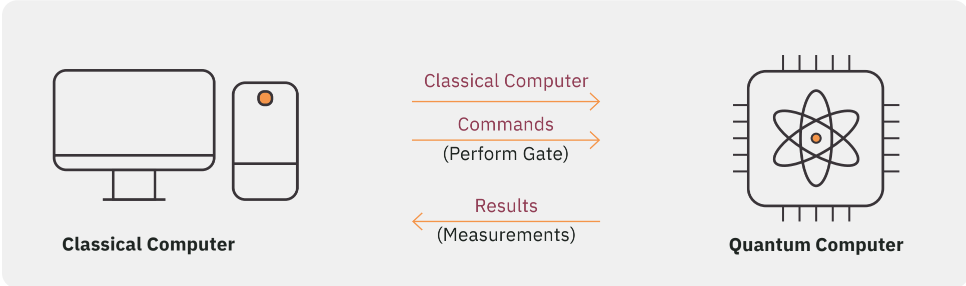
- In a classical l computer, all bits are “separate”, reading out a bit doesn’t tell you anything about any of the other bits. In quantum computing however, qubits can be “entangled” – by reading out a qubit you also know something about other qubit(s) that are entangled with this read-out qubit, and;

- In a traditional computer calculations are done through ”logic gates”. These transfer a single input to a definite output, e.g.: IF input 1 = Yes, AND input 2 = Yes, THAN output is Yes, otherwise output is No. In contrast, Quantum Computers do calculations through “quantum gates”. These quantum gates transfer a superposition of states of a qubits (or entangled set of qubits) to another superpositions of states on the qubit(s). Instead of having to deal with a single value at a time, a quantum gate can address a large array or set of values simultaneously. This is also referred to as parallelization. This ability to parallelize is ultimately key for its ability to speed up exponentially and deal with much higher degrees of complexity.,

Because a Quantum computer is only better in a certain types of problems, and a traditional computer is still much better (and expected remain more efficient) at many other problems, including more routine tasks (e.g., text & image processing), a quantum computer operates by being hooked up to a traditional compute. Therefore, it is sometimes also referred to as a quantum accelerator.

Clsssical computer	Finance	Quantum Computer	Aerospace and defence
Uses transistors which represent 1 or 0 (bits)		Uses quantum bit (qubits) which can represent 0 and 1 simultaneously	
Computing power scales 1-to-1 with number of transistors and clock speed		Computing power increases exponentially with number of qubits	
Use for General purpose		Use for certain problem classes: optimization, simulation and de-/ encryption	

3 of the key distinguishing features between classical and quantum computer are its information carriers (bits vs qubits), the way computation power scales and its applications



A Quantum computer is a device, operated by a traditional computer and only being employed for certain types of algorithms, by some it is referred to as a Quantum Accelerator, rather than Quantum computer.

Qubit quantity & quality drive performance and value in quantum computing

The higher the quantity and quality of qubits that can be operated effectively, the higher the Quantum Computer's performance and value.

What's the current state-of-the-art?
The current state-of-the-art is considered to be IBM's 433 qubit chip. IBM, and other Quantum Computing companies like Google, PsiQuantum and many others , have engineering roadmaps towards the # of qubits required for economic industrial use (estimates of 100'000-1'000'000 are often cited). Many consider the question regarding these roadmaps has shifted from "are they at all possible" to "how much capital and what risk is there on the timelines".

Presently the primary technological hurdle in making Large Scale Quantum Computers (LSQC) at economic industrial scale (faster at calculations than the most advanced classical super computers with economic value) is increasing the number of high-quality qubits on a chip, surmounting existing (physical & economic) scalability barriers.

What do the physical & economic hurdles look like?
Taking the "superconducting qubit" approach as an example: with the current architecture 1'000'000 qubits and its wiring wouldn't fit in a (standard) cryo-genic fridge and its massive amounts of wires (2-3 per qubit) and electronic signals would create excessive heating in the fridge. Different solution directions are explored to overcome these hurdles.

Also, the cost per qubit (including its wiring & control hardware) is currently ±10'000/ qubit - a 1'000'000 qubit system would be extraordinarily and probably even prohibitively expensive at this cost per qubit. Both Full stack and component companies aim to bring this cost per qubit down by at least 1-2 orders of magnitude.

Why are 100'000 to 1'000'000 qubits needed? Theoretically, (a few) hundred "perfect" qubits, also referred to as "logical qubits", would be enough for a Quantum computer for economic industrial use.

However, in real-life the qubits are imperfect and multiple imperfect qubits are needed to "simulate" a logical qubit. The higher the quality of the qubit, the less imperfect qubits are needed to simulate a logical qubit. Dependent on the technology and quality 1'000 – 10'000 such qubits are needed to make up a single logical qubit.

It should be noted that there is a lower limit to the qubits quality for this to work. When the quality is sufficiently poor, it doesn't matter how many qubits there are, it won't be possible to simulate a logical qubit with them.

Another critical metric is coherence time: how long information remains stored on a qubit. Extended coherence time facilitates more calculations per qubit during its coherence time and enhances overall computer performance.

Source: Arthur D Little, Google, interviews

Current state-of-the-art is considered to be IBM's 433-qubit quantum computer, called "Osprey". It was released 8 years after the release of their 5-qubit system. Many companies aim for 2030 to achieve economic industrial scale, where their Quantum Computer is faster that the most advanced classical (super) computers in certain types of calculations.

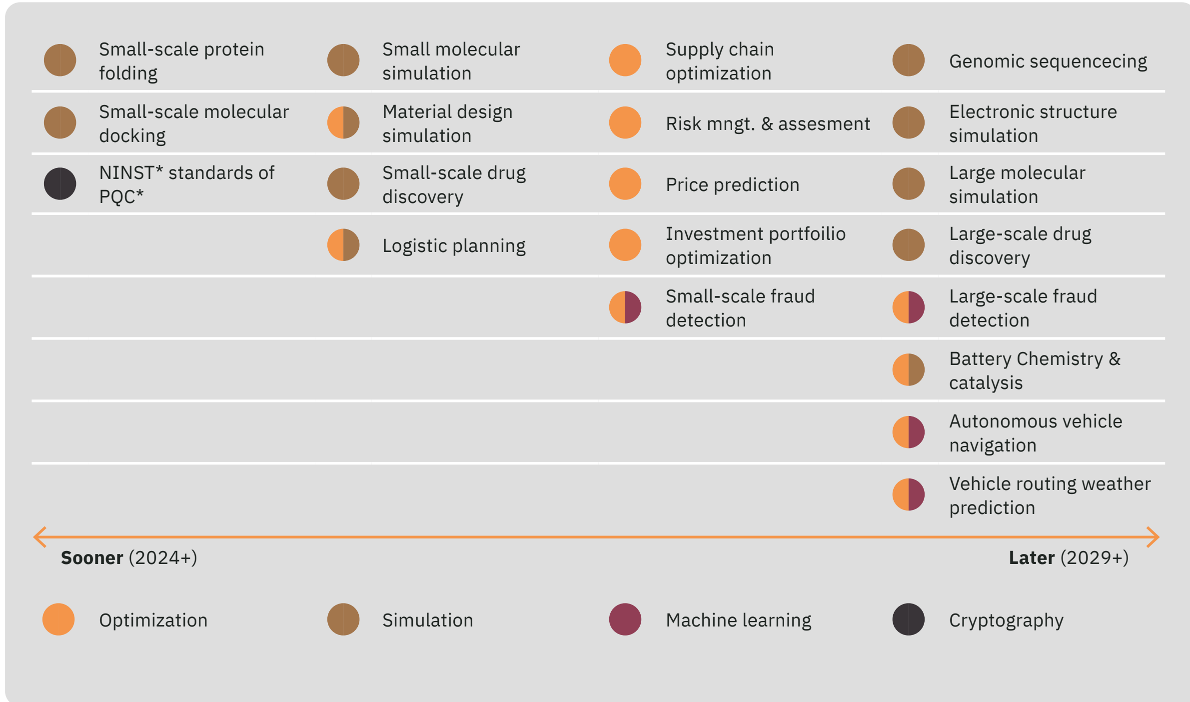


Chart from Arthur D Little Quantum Computing report May 2022. The applicability and value of the Quantum Computer will grow with its increasing number of qubits as it will be able to handle more complex problems.

There are multiple flavors of Quantum Computing, Large Scale Quantum Computer being the aim for most

It should be noted that there are different “types” of Quantum computers in development:

- **Large Scale (Universal) Quantum Computer (LSQC)**: is what is mostly referred to when talking about (the potential of) quantum computers. An LSQC is a Quantum Computer that can do all basic quantum operations and therefore perform all Quantum algorithms. It is “**error corrected**” meaning it can correct for any errors occurring on the qubits and “fault tolerant”, meaning it is designed in a way that faults/mistakes in operations are compensated for in a way that they don’t affect the intended operations/calculations. The aim is for LSQCs to have “**economic industrial scale**”: being of economic value by doing (certain) computational tasks faster than the most advanced traditional (super) computer. It’s the aim of ”full-stack” quantum computer developers (such as Google, IBM, PsiQuantum, Quantinuum, IonQ) to ultimately develop a LSQC.

- Noisy Intermediate Scale Quantum (computer) (**NISQ**): these are suboptimal LSQCs, with less qubits than an LSQC. They are not fully error corrected and/or fault tolerant, have only a limited number of qubits, they are (mostly) not supreme over traditional computers or only in a very limited subset of cases which are not considered to be economically relevant. NISQ can be very useful in research and developing & testing (quantum) algorithms – commercial applications for industry end uses are not foreseen;

- **Annealers** are not general-purpose Quantum Computers (like the LSQC), but specialized in a subset of Quantum Algorithms, mainly for optimization problems. It has advantages over traditional cases in a relatively narrow set of cases. There are already commercial Annealers; they will expect competition from increasingly capable NISQ and eventually LSQC;

- **Analog** quantum computers perform their calculations not by gates, but by e.g. moving quantum bits around to influence their states and entanglement. Because of this way of operation, it is referred to as “analog”. They are specialized in a subset of problems, mainly in simulating quantum phenomena. (Some) analog Quantum computers can (in principle) also work in a “digital mode”, i.e. with quantum gates.

- **Emulators** aren’t actual Quantum computers, but traditional (super) computers that simulate being a Quantum computer and thereby being able to execute Quantum Algorithms. Traditional computers can only simulate simple (low # qubits) Quantum Computers, and obviously don’t have the computing power to simulate a Quantum Computer than is more powerful than itself. Emulators’ most notable purpose is to optimize Quantum Algorithms and software for actual (similar and larger scale) Quantum Computers;

Source: Arthur D Little, Quantum Insider, interviews

Quantum emulators (in conventional computers)	Quantum annealing computers	Analog quantum simulators	Universal quantum computer (gate-based)	
			NISQ • No error correction • Limited number of noisy qubits	**LSQC** • Error correction and fault tolerant • High number of stable qubits
• Used to execute quantum algorithms on traditional computers • They execute these algorithms, quantum gates, and qubits with the processing capabilities of traditional computers, using large vectors and matrices	• Based on low-quality qubits • Use a slow and controlled evolution of a set of qubits, initialized in vva state close to the solution • Advantage over conventional computing is still limited for complex problems	• Serve as simulators of quantum phenomena without using gate-based qubit system • Analog, not digital • Most commonly used technique is cold atoms cooled and controlled by lasers	• Universal quantum computers use qubits with quantum gates • Offer optimal speed gain vs,. conventional computers for multiple applications	
Main use Quantum algorithm debug and verification	**Main use** Quantum algorithm debug and verification	**Main use** Lab tools for quantum physics simulation	**Main use** General-purpose QC applications	

Chart from Arthur D Little Unleashing the business potential of Quantum computing report, Sept 2022. There are several classes of Quantum Computers. Emulators, Annealers and small Analog simulators are already in operation and least difficult to realize. The big “Pie in the Sky” reamins the LSQC

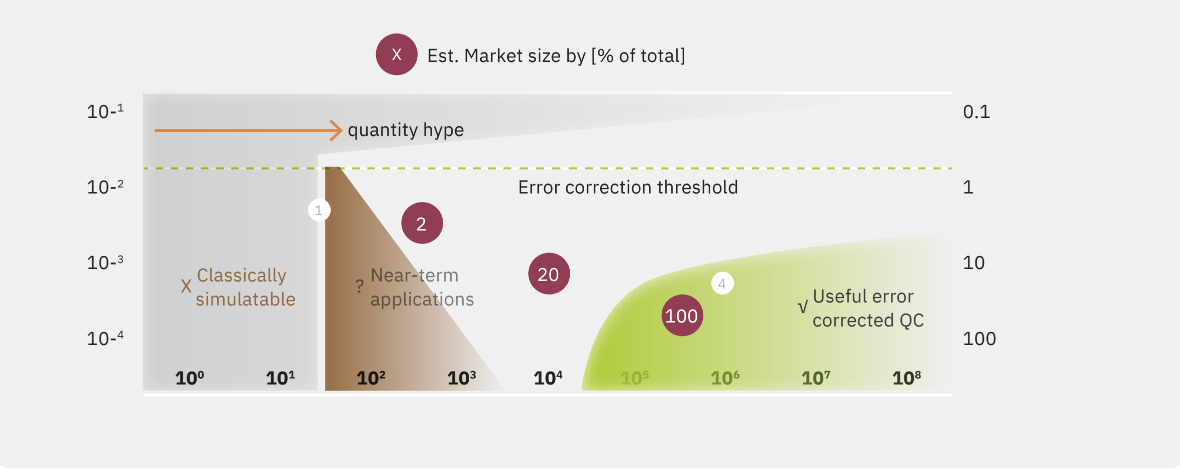


Chart from Google, in combination with data interpreted from Arthu D Little, BCG, McKinsey. The applicability and value of the Quantum Computer will grow with its increasing number of qubits as it will be able to handle more complex problems.

In recent years new players emerged, challenging the incumbents with other types of qubits

Starting around 2014, private entities began participating in the development of a “Full-stack” Quantum computer. Notably, the Canadian company D-Wave was founded in 1999 and is considered the earliest successful Full-stack player, although their system was limited to Annealing (performing only a subset of a general-purpose Quantum Computer).

Around 2014 the most advanced, scalable and promising technology was superconducting qubits, leveraging existing manufacturing infrastructure. Despite significant scaling challenges, the field expressed - with increasing confidence – that these obstacles could be overcome. The most notable players that adopted this path are Google and IBM.

Subsequently, various start-ups emerged, opting for different and novel qubit types that they believe to be more scalable, economical or suited for certain computations.
Currently the 5 most promising and funded qubit types are: superconducting, (electron) spin / quantum dots, trapped ions, trapped cold atoms, photonics.
Remarkably, most roadmaps across these different qubit types coincide in terms of their projected year for achieving economic industrial scale, ± 2030.

Debates revolve around two main points.
The first centres on which qubit types will ultimately succeed and which one will be first. The first to reach economic industrial scale and commercialize will gain relative advantage as the eco-system, most notably downstream (application(s) software), will be expected to gear itself towards the winning technologies, raising the hurdles for other qubit types.
At this stage it is still very difficult to predict. Although divergent views persist, practically all experts, also those with vested interests or work-related biases, believe it’s still ”up in the air”, a sudden breakthrough in a (rival) technology could upend the status-quo and put a qubit far ahead of its rivals.

For many Superconducting qubit technology is still a favourite (save bet), because it’s currently most developed, and deep-pocketed players such as IBM and Google have opted for this approach.

Secondly, there are discussions around whether LSQCs based on different qubit types can economically co-exist. Perspectives generally fall into three categories:
1) a single winner takes all (over all qubit types);
2) there will be 2-3 players competing, adopting the best type of qubit which can be the same or different, or;
3) there would be 1-3 players per qubit type, over multiple qubit types (2-5). Because each qubit has its own (computational) (dis)advantages with respect to the others, they will coexist, playing into their own strengths. Some of the interviewees pointed out the advantages of combining solutions, based on different qubit types, in a single device. Some of the qubit differences have a big impact on how they can be used, e.g. “analog” vs. “digital”. Other differences are more subtle: different qubit types (with different chip designs and surface codes) could be more efficient for different calculations or performing certain tasks (like holding quantum information). Conceptually analogous to traditional computing solutions 1 or several components (like a: CPU, GPU, FPGA and different types of memories)can be combined, dependent on the devices’ purpose. Geopolitics could influence the number of players in each of the qubit types (e.g. non-open markets are expected to lead to local champions).

Among those having broad access and an understanding of the various technologies, the 3rd view is most widely adopted.

Source: Arthur D Little, BCG, Innovation Industries, McKinsey, Expert interviews

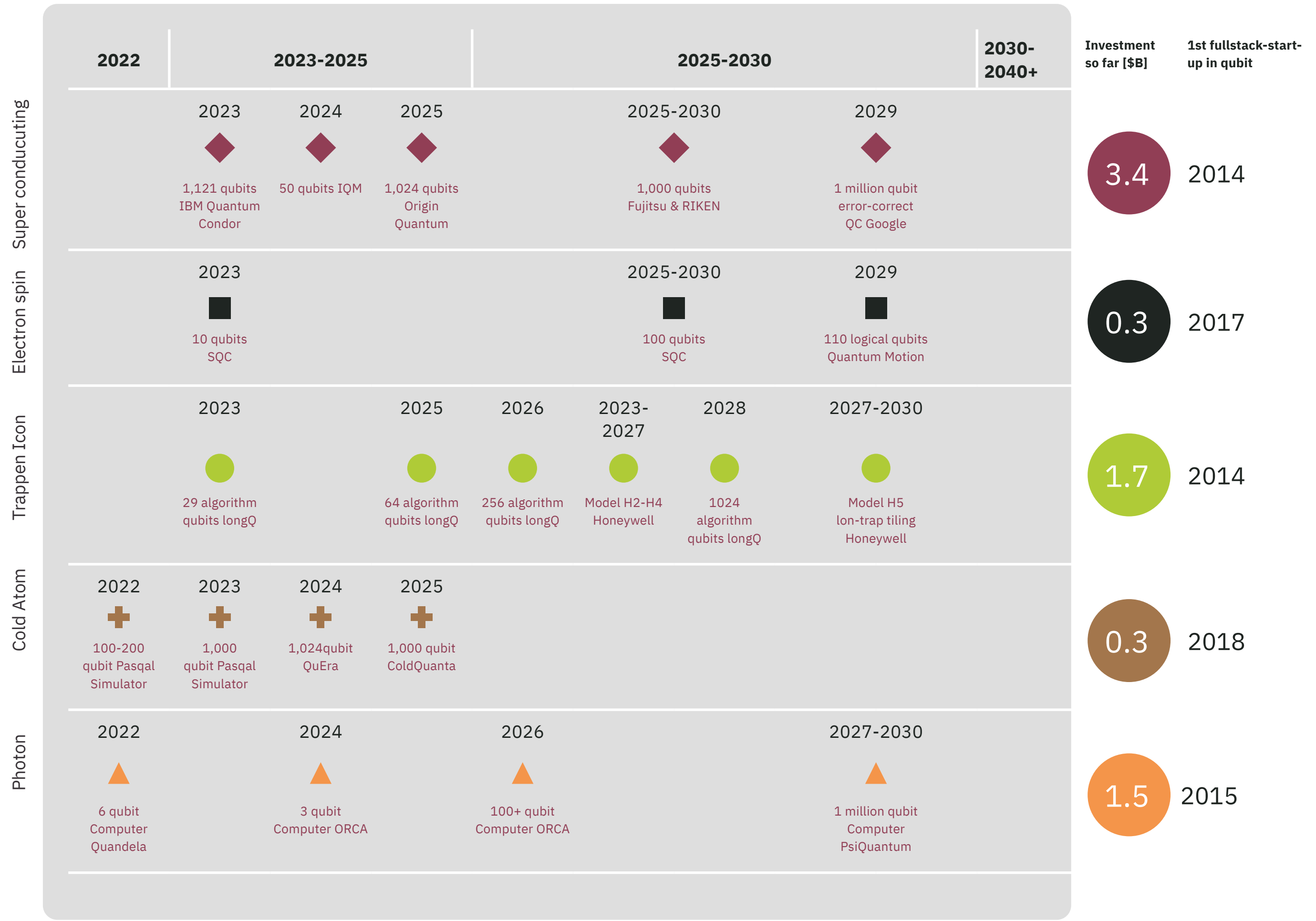


Chart from Arthur D Little Quantum Computing report May 2022, showing different full-stack players racing to develop the first LSQC based on 5 different types of qubits, complemented with data on total investment in qubit type and starting year of the first start-up in the respective qubit.

While previously many believed “1 horse would win the race”, currently the prevailing view is that LSQCs of different qubit types will co-exist because of the different pros and cons (and types of calculations the qubit type is most efficient for) – and that 1-3 players will compete in each qubit type.

Source: Arhur D Little, Olivier Ezratty; BCG, Innovation Industries, interviews

Quantum Communication ensures inherently save communication and enables Quantum computers to communicate

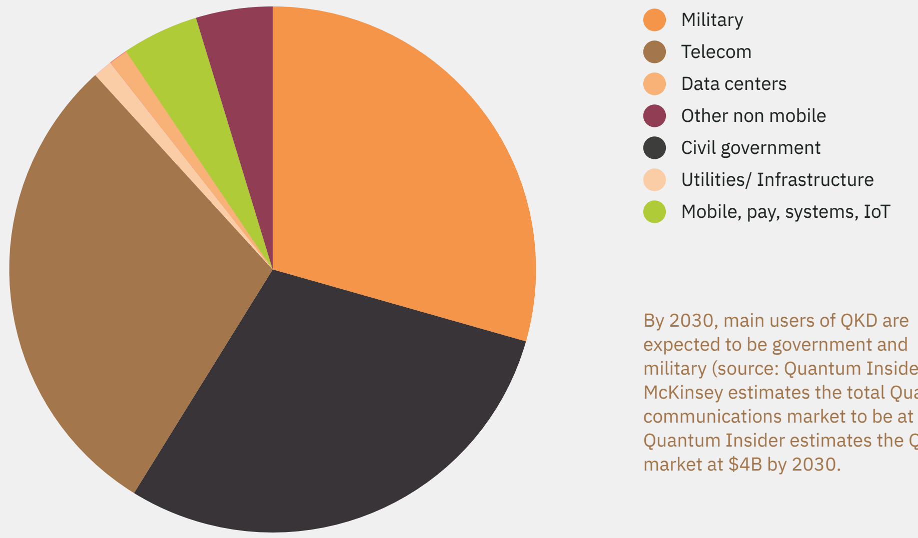
In Quantum Communication the 2 main markets/applications are considered to be:
- Quantum Key Distribution (QKD), an inherently secure communication, free of eves-dropping, based on a protocol that relies on several quantum mechanical phenomena, and the transmission of qubits from a sender to a recipient;
- Quantum internet, transferring quantum data from one quantum computer to another by qubits.

On the short to midterm it's mostly expected that the QKD market will consist of military, (semi)government agencies and industry parties where secure communication have above-average value (e.g. banks, trading). With decreasing terminal cost (currently at >€10k and aimed drop significantly over the next 10-15 years), wider adoption and new types of use cases are expected.

Quantum internet enables Quantum Computers to exchange quantum information directly (i.e. not having the need to decode quantum information into classical information and sending it over regular internet, after which it needs decoding again into quantum information); this has a significant advantage and speed-up over classical communication infrastructure. This market will rely ans scale with functional quantum computers and is therefore expected to be lagging and, at least initially, smaller than that of Quantum Computers.

Both for QKD and Quantum internet it remains to be seen what the dominant protocols and standards will become on which other parties can engineer applications and (auxiliary) equipment. Most companies and countries are developing their own standards and protocols at the moment.

Market segments estimate for Quantum Key Distribution (QKD) by 2030



By 2030, main users of QKD are expected to be government and military (source: Quantum Insider). McKinsey estimates the total Quantum communications market to be at $1-7B, Quantum Insider estimates the QKD market at $4B by 2030.

Quantum Sensing delivers a massive increase in performance, is most near term, but still niche

Quantum Sensing is the most mature domain with the most revenue being realized at industry end users. There are already commercial applications, most notably:
- Magnetic sensors;
- Light sensors (LIDAR, single photon detectors);
- Atomic clocks;

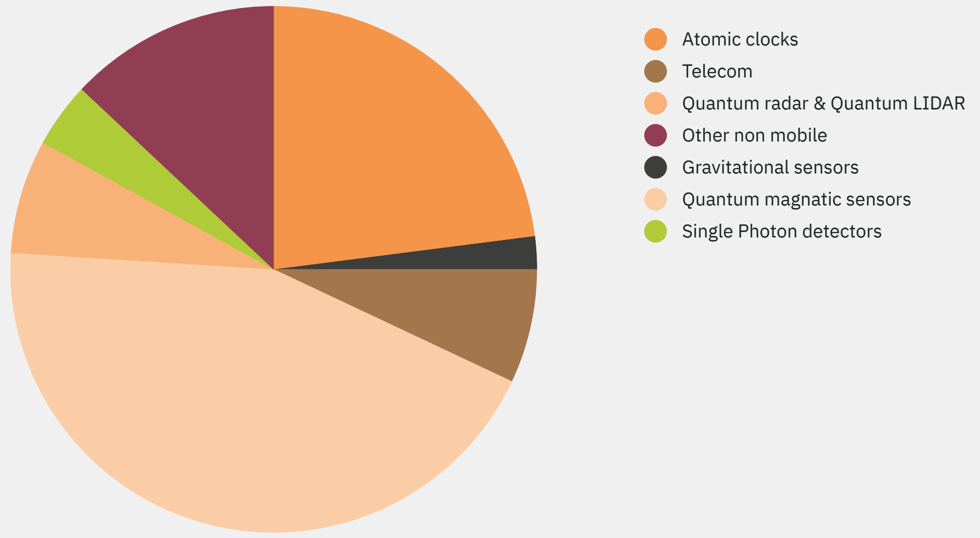
Exploiting the quantum mechanical properties, quantum sensors are up to multiple orders of magnitude more sensitive than their non-quantum-mechanical counter parts.

Currently the market is being estimated to be $0.5-1B (dependent on definition and source) and is growing with an estimated ±15% CAGR

Though it is most mature and nearfield, its applications so far are more "niche" compared to Communications & Computing (e.g.: use in satellites, medical diagnostics), in part because of its relatively high terminal cost compared to its non-quantum (less sensitive) counterparts.

Source: CB Insights, Quantum Insider, McKinsey, interviews

Expected market segments for Quantum sensing until 2030



Source: Quantum Insider

Quantum Delta NL has been championing the NL's national Quantum agenda and (pro)actively builds the eco system

Quantum Delta NetherLands (QDNL) is an organization, funded by €613M of the Nationale Groeifonds (National government's "Growth Fund") with ahe ultimate to tap into Quantum Technology's revenu potential and create high value-add jobs. In order to do this it has 3 main aims (CATs), realizing:

1. a full-stack quantum computer;
2. National Quantum Internet
3. Ecosystem of Quantum sensing companies

Quantum Delta does this by supporting Academia and Industry through a.o. (SME) grants and building (shared) facilities.

In addition Quantum Delta has a €15M investment fund, "**Quantum Delta Participations 1**" that is used to invest in early stage start-ups (pre-conception – seed).

It has participations in Quantware, Qbird and Fermioniq as well as several Quantum start-ups that are still in Stealth mode.
A second, larger Quantum Delta Participations Fund is currently being established.

Through these grants, investments and facilities, it is building out and fostering the Quantum ecosystem in the Netherlands.
InfitintyQD is a service provider that connects and supports Quantum entrepreneurs with professional services & skill building that they need to succesfully launch their company and secure their first funding.

Four action lines and three ambitioous unifying CAT programmes

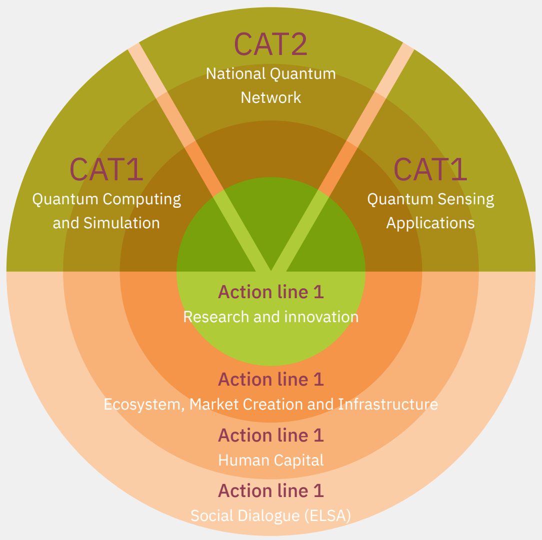
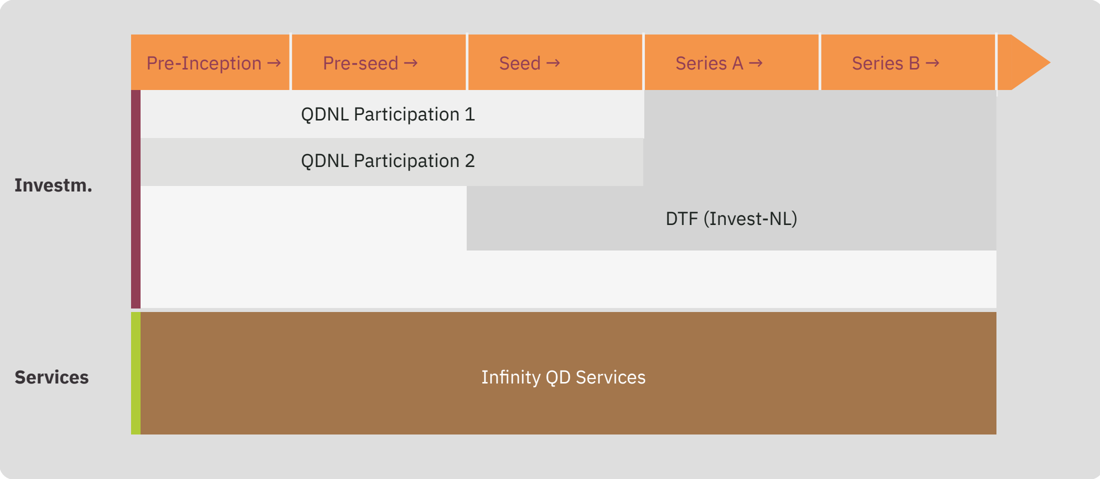


Chart with overview of Quantum Delta's focus areas and approaches;

QDNL Participation, Invest-NL's Deep Tech Fonds and Infinity QD supports Quantum Technology start-ups throughout the early stages of their journey



OK, so how's NL doing?

Netherlands' global position and national ecosystem

Courtesy of Qblox

The Netherlands relatively high quality Academia & workforce

Academic output and other (absolute) output measures indicate The Netherlands has a relatively high-quality academia and effective Quantum workforce.

In academia, Delft University has been a leader in Quantum Technology, evident in the quality of its research publications. Delft's proficiency in Quantum Technology has been bolstered by its collaborations with Microsoft, Intel, and Fujitsu, along with TNO. Together, they have been competing with Google, IBM, Honeywell and others in the race to develop an LSQC at enonomic industrial scale.

Outside of Delft, other Dutch universities in Eindhoven, Twente, Leiden, and Amsterdam have been seeing a growing number of Quantum Technology research groups.

The significant investment in academia has resulted in a relatively large and highly skilled quantum workforce on a per capita basis, though in absolute terms (of course) modest compared to a few of the bigger countries.

Most rankings topped by USA & China. Other "high ranking" countries: Canada, Japan, UK, France, Germany, Australia

Rank by #-of tier publications[1]		3 y change in %
1. Univ Sci & Technol China (CN)	147	48%
2. MIT (US)	129	40%
3. Delft Univ Technology (NL)	112	51%
4. ETH Zürich (CH)	103	51%
5. Univ Maryland ((US)	98	45%
6. Harvard Univ (US)	89	46%
7. Univ Copenhagen (DK)	87	43%
8. Unive Calafornia Berkeley (US)	79	46%
9. Univ Oxford (UK)	78	46%
10. National Univ Singapore (SG)	76	55%
11. Californai Inst. Technology (US)	75	47%
12. Univ Waterloo (US)	74	45%
13. Tsinghua Univ (CN)	71	49%
14. Univ Tokyo (JP)	69	51%
15. Sorbonne Univ (FR)	64	50%

Rank by #-of graduates of Quantum-relevant studies2 / mn inhabitants		3 y change in %
1. Denmark (DK)	645	48%
2. France (FR)	438	40%
3. United Kingdom (UK)	392	51%
4. Germany (DE)	356	51%
5. Australia (AU)	280	45%
6. Switserland (CH)	280	46%
7. Netherlands (NL)	263	43%
8. Poland (PL)	249	46%
9. United States (US)	242	46%
10. India (IN)	217	55%
11. Italy (IT)	175	47%
12. Spain (ES)	158	45%
13. China (CN)	157	49%
14. Russia (RU)	137	51%
15. Korea (KR)	116	50%

- 10th in public investment (2nd per capita, after Germany)
- >13th in # of Quantum related graduates (7th per capita)
- 3th institute w. highest # top-tier publications, and
- 4th institute w. most cited pubublications
- 7-9th in private investment (<10M);
- 10th in # of Quantum Computing start-ups
- 7th in # of Communication, and
- 7th in # of Sensing start-ups

Source: McKinsey Quantum-Delta report, 2021; McKinsey "Quantum Technology monitor, Apr 2023"

The Netherlands' commitment to Quantum Technology reflected in its public funding (per capita)

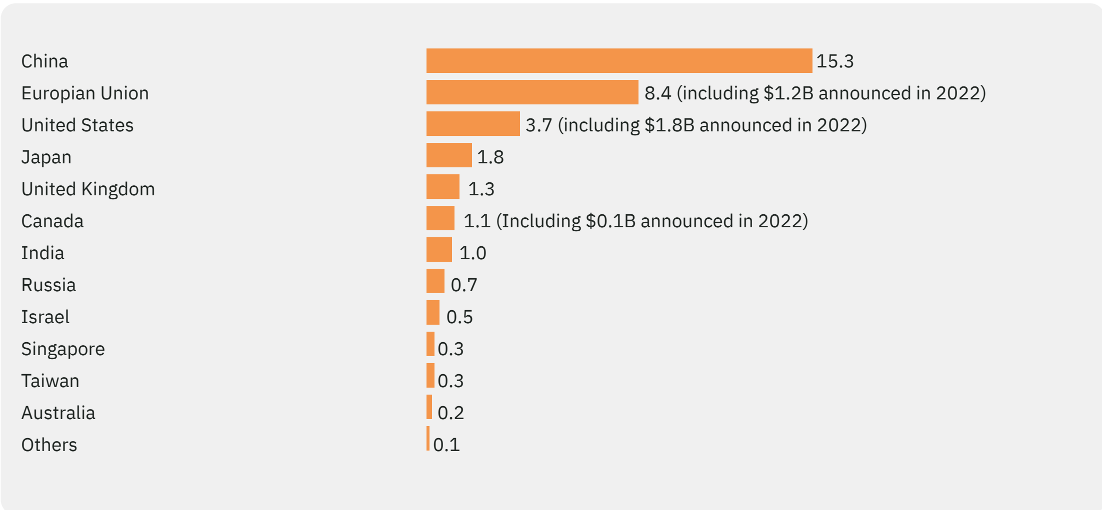
Investment in Quantum Technology has been steadily increasing in multiple advanced economies as its practical applications draw nearer.

The Netherlands is employing its own dedicated national €613 million program, managed by QuantumDelta Netherlands, along with EU Quantum tech funding and regular academic funding.

The most recent significant announcement came from the United Kingdom, who will start a £2.5 billion program for the next decade. The national programs can differ in focus. Some are concentrating on preparing their economy and workforce, while others are more oriented towards technological advancement. As discussed earlier in the report, the main focus of The Netherlands' current program is supporting the creation of a Quantum Computer, Quantum Internet and eco system of Quantum Sensing companies.The Netherlands currently ranks second in terms of per capita public spending among the 12 largest public investors, coming after Germany and ahead of Israel. However, when it comes to total spending, the Netherlands ranks 10th, with China surpassing all others by a significant margin.

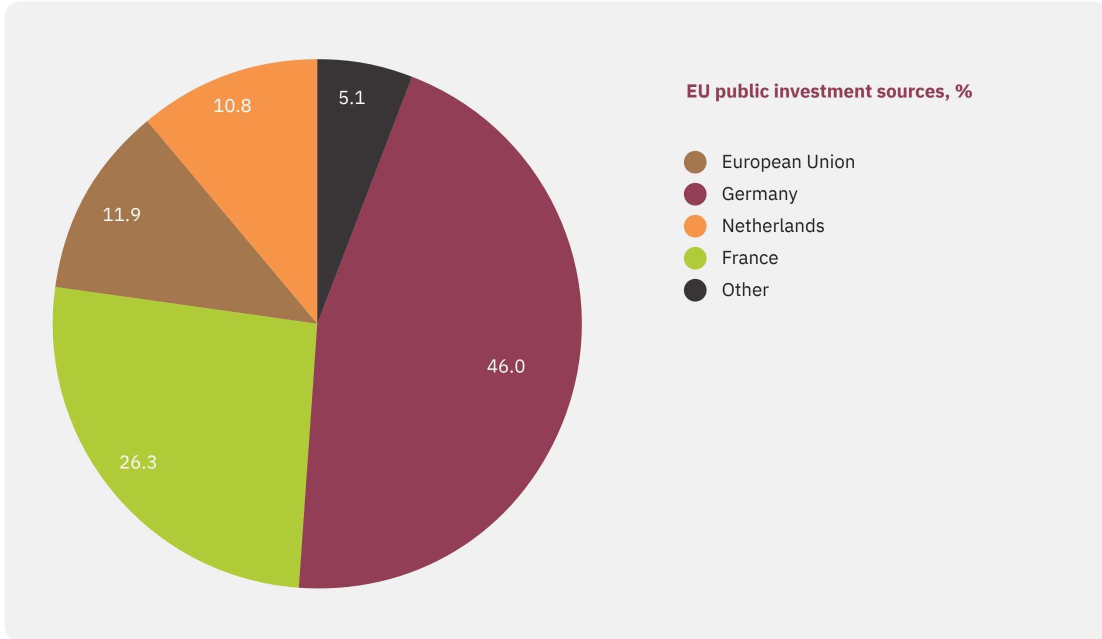
Currently, the most significant developments in commercial quantum technologies and applications are driven by private companies, often working closely with academic institutions. The major players in this field include the United States, China, Canada, Japan, the United Kingdom and France. This dominance is evident in the investment in startups, national programs, as well as the number of patents, startups, and graduates in the quantum field.

Announced govermental investment[1], $ Billion



Source: Johnny Kung and Muriam Fancy: *A quantum revolution: Report on global policies for quantum technology*, CIFAR, April 2021; press search
Exlcuding GBP2.5B program recently announced by UK

1. Total historic announced investment; timelines for investment vary per country



Country	Funding per capita [$/p]	Ranking #
Germany	77	1
Netherlands	51	2
Israel	48	3
Canada	42	4
UK	37	5
France	34	6
China	18	7
EU	16	8
Japan	14	9
US	11	10
Russia	6	11
India	1	12

Exlcuding GBP2.5B program recently announced by UK

Source: McKinsey Quantum Technology monitor April 2023

More and/or dedicated facility capacity is the companies’ main perceived bottleneck in innovation speed and growth rate

The main bottleneck in innovation for the hardware & full-stack companies is more (or dedicated) capacity in facilities, most notably:

- Clean room,
- Testing set-ups;
- (Photonics) nano-fabrication / foundry;

On a very positive note, it is felt that in terms of the facilities’ capabilities, they are currently mostly on par and that the new planned facilities are expected to be on par as well (though only 1 or 2 cases room for improvement still).

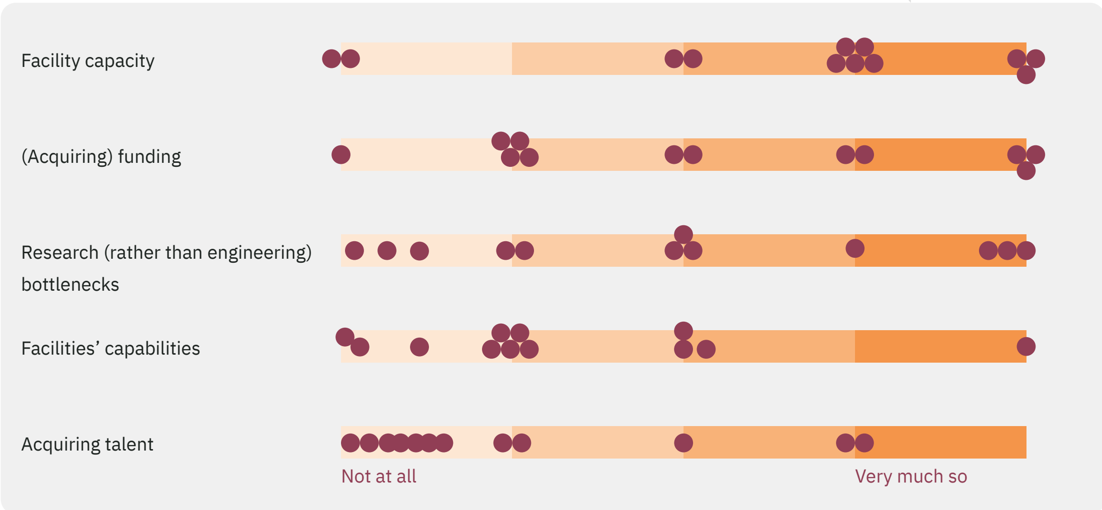
Also, recruiting technical talent for most areas of expertise is still doable.

However, it is expected (voiced by TTOs) that this is expected to change as the ratio of Quantum start-ups vs. Quantum Academia is increasing. Also, positions most difficult to fill are those where there is strong cross-industry competition and/or highly specialized on a most senior level.

Funding is a serious bottleneck for most because of the high capital requirement for R&D. Furthermore, TTOs mention #1 issue is attracting good managers/executives and/or entrepreneurial experience/mindset to complement the academic founders and growing team.

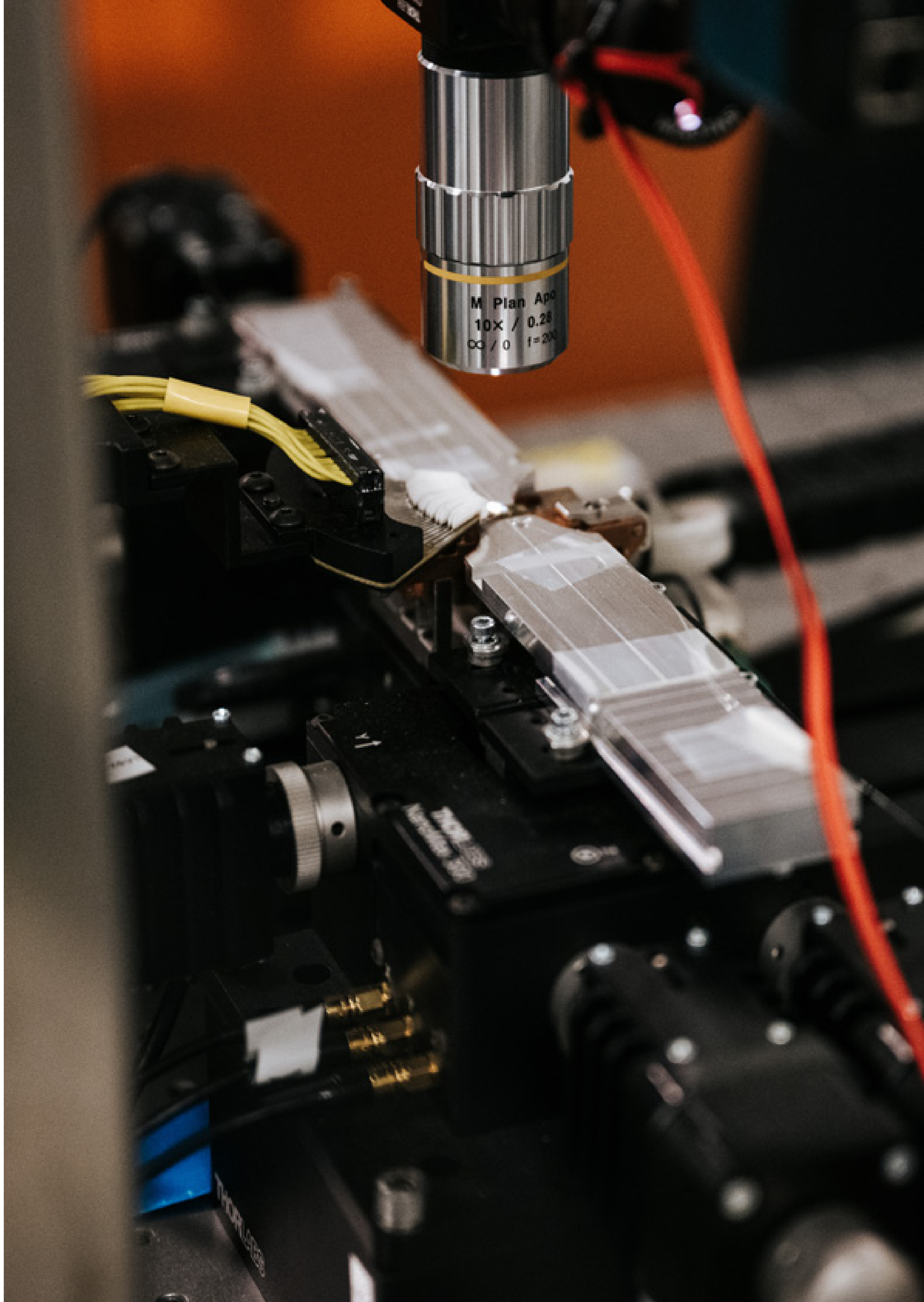
> “Facilities are good, but a lot of time is wasted (and competitive advantage lost) because of availability or reconfiguruing (shared) facilities”

What are you main bottlenecks in innovating & growing revenu more quickly ?



Source: interviews with Quantum start-ups

> “As long as your pay market conform and are willing to pay the recruiter, you get the talent you need”



Upstream eco-system very well developed though only 1 full-stack player in Computing and 1 in Communications

There are currently 14 Quantum start-ups; start-ups that sell Quantum Technology and/ or are focused on developing equipment/ components that are in the critical path of Quantum Technology progress.

There is currently only 1 company openly aspiring to be a Full Stack1 Quantum Computer company (QuiX) and 1 (Qbird) being a Full-stack Quantum Communication2 company. Most start-ups are upstream in the value chain, making components and equipment for Quantum Technology academia and R&D groups.
Though not visible from the chart, in the vast majority of cases, these start-ups are in a local eco system with a strong presence of the capabilities (nano-fab, advanced electronics, ..) that these start-ups require in order to progress through their tech roadmaps.
Most companies in Computing are centred around Superconducting-, Spin- and Photonic qubits. Where most activity around Superconducting and Spin qubits is located in the Delft area and photonics is mainly in the Twente area.

In terms of revenues and value, the prevalent opinion amongst VCs as well as TTOs and academics is that in the coming years most activity, revenues and value will be in hardware, equipment and components. And once (a) hardware standard(s) are being established it becomes more value will start coming from downstream in the value chain, i.e. Application software and services – this is analog to the developments in semicon (classical computing).

There seems to be relatively little activity still in Quantum sensing in the Netherlands at the moment.

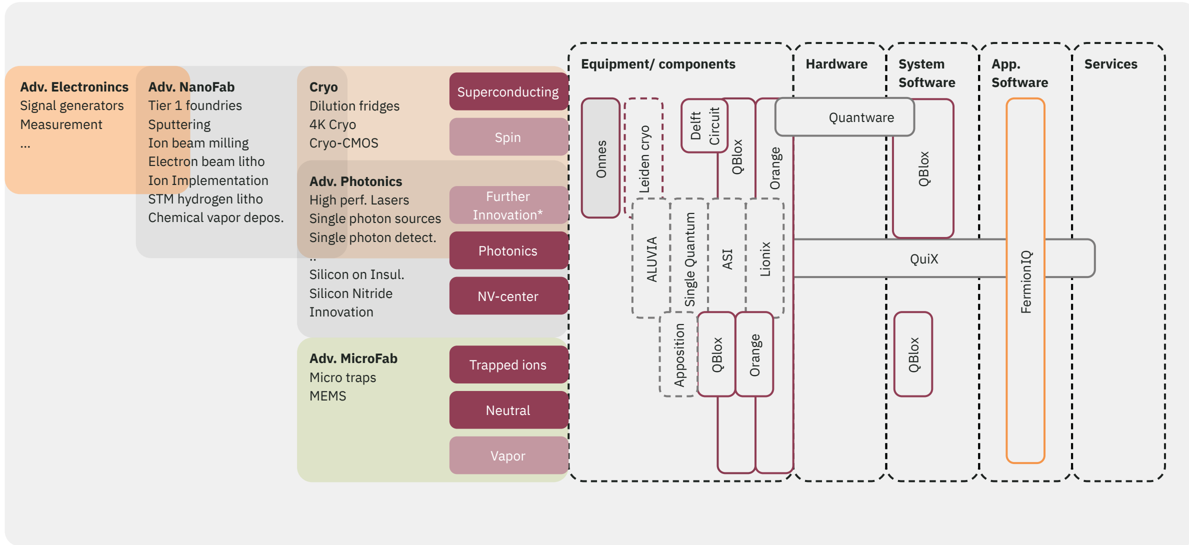
Company name	City	Domain	Value chain	Qubit type
QuiX	Enschede	Computing	Full Stack	Photonics
Quantware	Delft	Computing	Hardware	Superconducting
Qbird	Delft	Communication	Full Stack	Photonics
Qphox	Delft	Comp./ Comms.	Hardware	Photonics
LioniX	Enschede	Computing	Hardware	Photonics
Qblox	Delft	Computing	Equip./components	All*
Orange QS	Delft	Computing	Equip./components	All*
Single Quantum	Delft	Comp./ Comms.	Equip./components	Photonics
ASI	Amsterdam	Computing	Equip./components	All
Delft Circuits	Delft	Computing	Equip./components	All*
Onnes	Leiden	Computing	Equip./components	Supercond. /Spin
Leiden Cryogenics	Leiden	Computing	Equip./components	Supercond./Spin
FermionIQ	Amsterdam	Computing	Application software	All*
Qu&Co	Amsterdam	Computing	Application software	Neutral Atoms

Quantum Technology start-ups in the Netherlands
*could in principle serve all qubit, but would require (significant) tech pivot

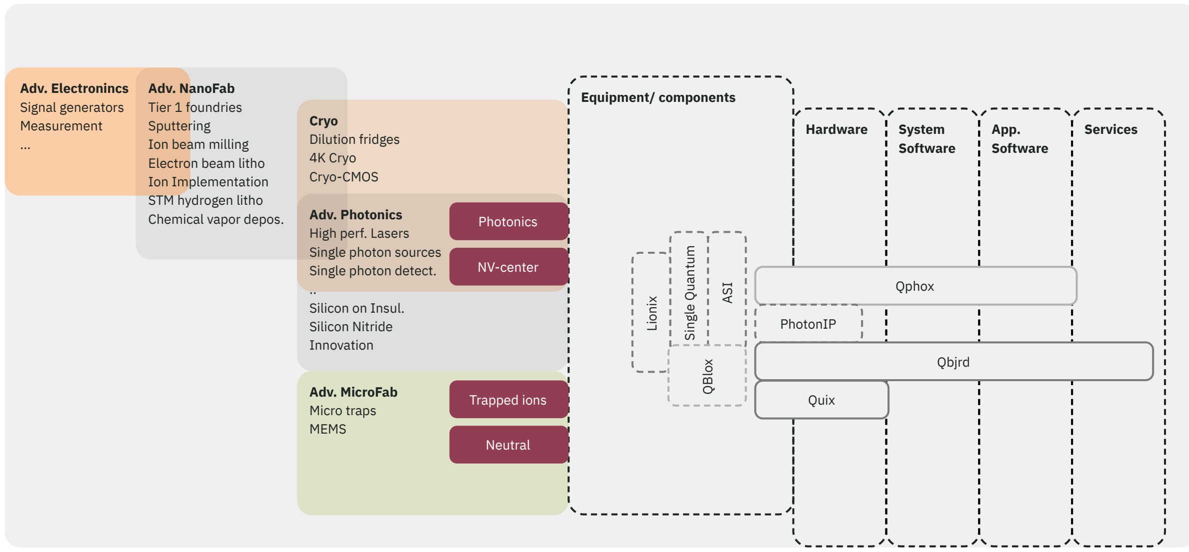
1. Full-stack player in Quantum Computing refers to a company that makes and sells fully functional Quantum Computers, at least up to the control software (not necessarily application software and services). Among Full-stack players, there are different degrees of vertical integration, i.e. the number of (sub)systems a company makes itself vs. sourcing. Though they might source some of its critical components, in this report a Full-stack player refers to a company that ultimately sells a fully functioning Quantum Computer.
2. Full-stack player in Quantum Communication is a company that makes and sells (a) scalable QKD/Quantum communication network(s) that can also be hooked up to a PC (QKD) or Quantum Computer (Quantum communication/internet).

Commercial
Not yet commercial
Color indicates what capability the main enabling tech relies on
[grey background]: not in critical development path for QC
[dashed]: customers outside of QC

Netherlands' Quantum Computing start-up ecosystem



Netherlands' Quantum Computing start-up ecosystem



Computing:
only QuiX "vertically integrated" (depicted horizontally) through the value chain. Most companies are upstream. Communication: Qbird and Qphox (highly) "vertically integrated" in communications. Qbird aiming for both scalable QKD and Quantum network. Definitions od the value chain stages (Components/Equipment, Hardware, etc.) based on McKinsey Quantum Technology Monitor, April 2023.

*Majorana fermion, Flip-flop, etc.

Sources: Company websites, InifityQD, FactBased Insight, McKinsey, BCG, interviews

Eco system NL most developed upstream

The 5 main hubs around which most activity is centred are Delft, Eindhoven, Twente, Leiden and Amsterdam with a total of almost 100 academic principle investigators, 14 active Quantum start-ups and several more start-ups being prepared for launch. Where Delft, Twente and Eindhoven are geared more towards hardware development, Leiden and Amsterdam are geared more towards algorithms and quantum software development.

Some of the notable institutes are:

QuTech (300 FTE) has been the most prominent institute, founded in 2014 and is a collaboration with between the **TU Delft**, **TNO**, **Microsoft**, **Intel** and **Fujitsu**. With 23 research groups (growing to ±27 in next years) it's the biggest Quantum Technology institute in the Netherlands and internationally see as being on the forefront of Quantum Technology development. Its main aims are to build LSQC as well as a quantum internet. It's mostly focused on Superconducting & Spin qubits.

QuSoft, founded in 2015, as a collaboration between the University of Amsterdam and Centrum Wiskunde & Informatica (English: Center Mathematics & Data science) focuses on the development of new (quantum) protocols, algorithms and applications that can run on small to full-scale prototypes of a quantum computer.

AQA in Leiden, with 4 assistant/associate professors associated to it, study quantum algorithms and their application in natural sciences (physics, chemistry) and practical computing (machine learning, Artificial Intelligence (AI), optimization) and the use of AI in Quantum Computing (e.g. calibration of qubits). In addition, Leiden brings in development and expertise on cryogenics which is important for several of the Quantum Computing approached.
TU Twente's QUANT institute and Eindhoven's Centre for Quantum Materials and Technology focuses on various Quantum Technologies with an emphasis in Twente on photonics related Quantum Technology (using photonics for qubits) and in Eindhoven on materials, cryptography and quantum simulation with cold atoms.

TNO in Delft performs contract research for (inter)national companies, such as Microsoft and Intel in all domains of Quantum Technology. It has approx. 120 researchers (PhD+) and state-of-the-art facilities (only 3-4 other locations worldwide are as advanced) that are also being used by start-ups. It is well positioned in the ecosystem as well as connected to Industry and government partners.

Source: interviews TTOs, "Invest in Holland"

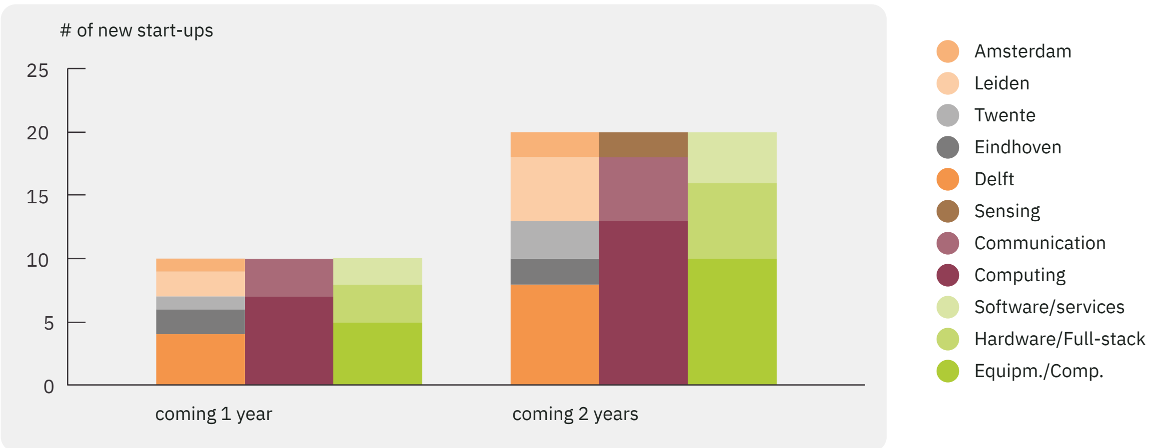
Though stalling globally, Quantum start-up creation is accelerating in the Netherlands

In the early 2000s, a surge in Quantum startups set the stage for remarkable growth, resulting in a total of approximately 350 startups by the year 2022. Since it has been slowing down globally. In the Netherlands however it seems to be speeding up.
This is partly due to a growing Quantum R&D market to which equipment & component and hardware companies can sell to. In addition also policies promoting starting up Quantum companies (championed in a large part by Quantum Delta) as well as the availability of pre-conception funding have been lowering the hurdles for academics starting a Quantum Tech company.

Some of these ventures, of which most in Communication and Sensing, have already been catering directly to governmental and industrial end-usersIn quantum computing, the primary customers for components and equipment are still for >90% academic groups and other start-ups engaged in quantum computer development.

Of the 15-20 additional Quantum start-ups that are expected to launch in the coming 2 years, 70% is expected to be in Computing, 30% in Communications (and perhaps 1 start-up in Sensing). 50% of these 15-20 are in components/equipment, 30% hardware/full-stack, 20% in app software/services.

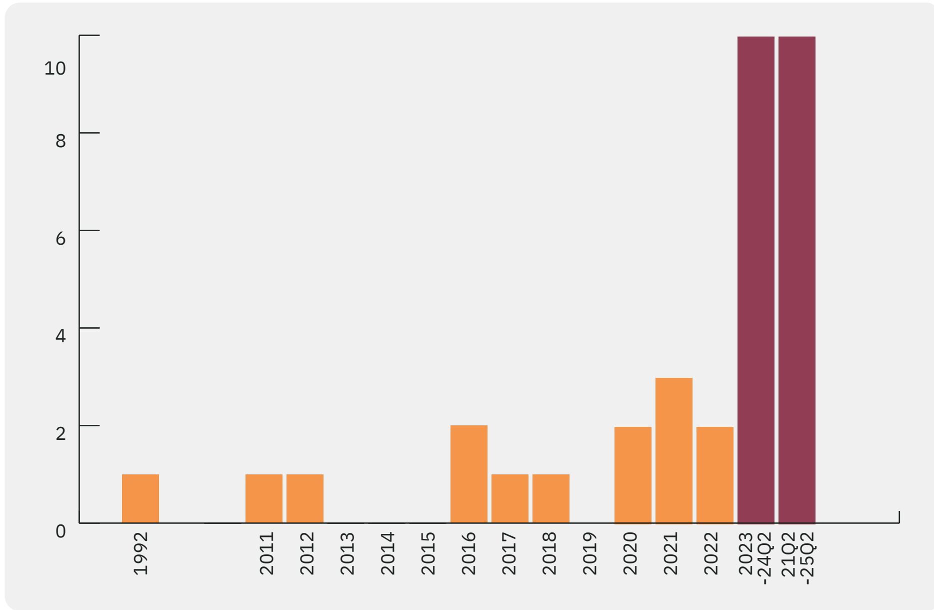
Anticipated NL Quantum Technology start-ups: location, technology domain & position value chain



Most anticipated Quantum Tech start-ups are in Computing and Communication, maybe 1 in Sensing. In both Computing and Communications there is still a strong emphasis on hardware.

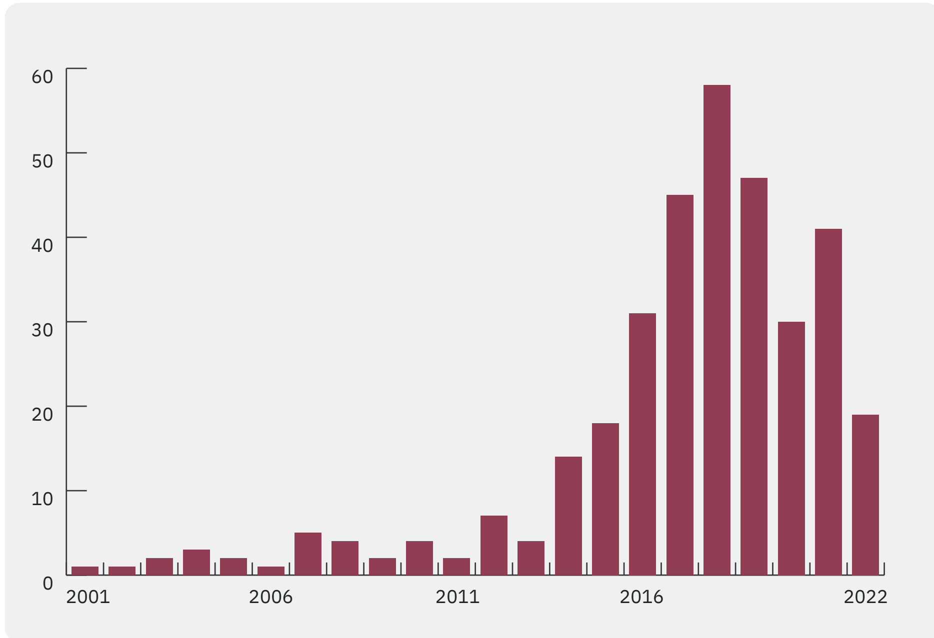
Though stalling globally, Quantum start-up creation is accelerating in the Netherlands

Global Quantum Technology start-up conception



15-20 new Quantum Technology start-ups are expected in the next 2 years, with 5-10 in the coming year (chart top right and below show high end of the estimates)

Global Quantum Technology start-up conception



Source chart top: McKinsey Quantum Technology Monitor April 2023,
Source chart left and below: TTO interviews

OK, so what’s needed? Who’s investing?

Quantum tech investment landscape

Courtesy of Qblox

Funding requirement Quantum start-ups on the radar altogether €1-2B, of which 50% for full-stack players

It’s estimated that €1-2B is required to get all current 14 (+4 in stealth mode) Dutch Quantum Technology start-ups to their intended market and profitability. This is a factor of 1.5-2 times higher than the estimates from the Quantum Technology companies (and TTOs) themselves, applied on the basis of experience of several Deep Tech investors on estimate accuracy over the concerned timelines.

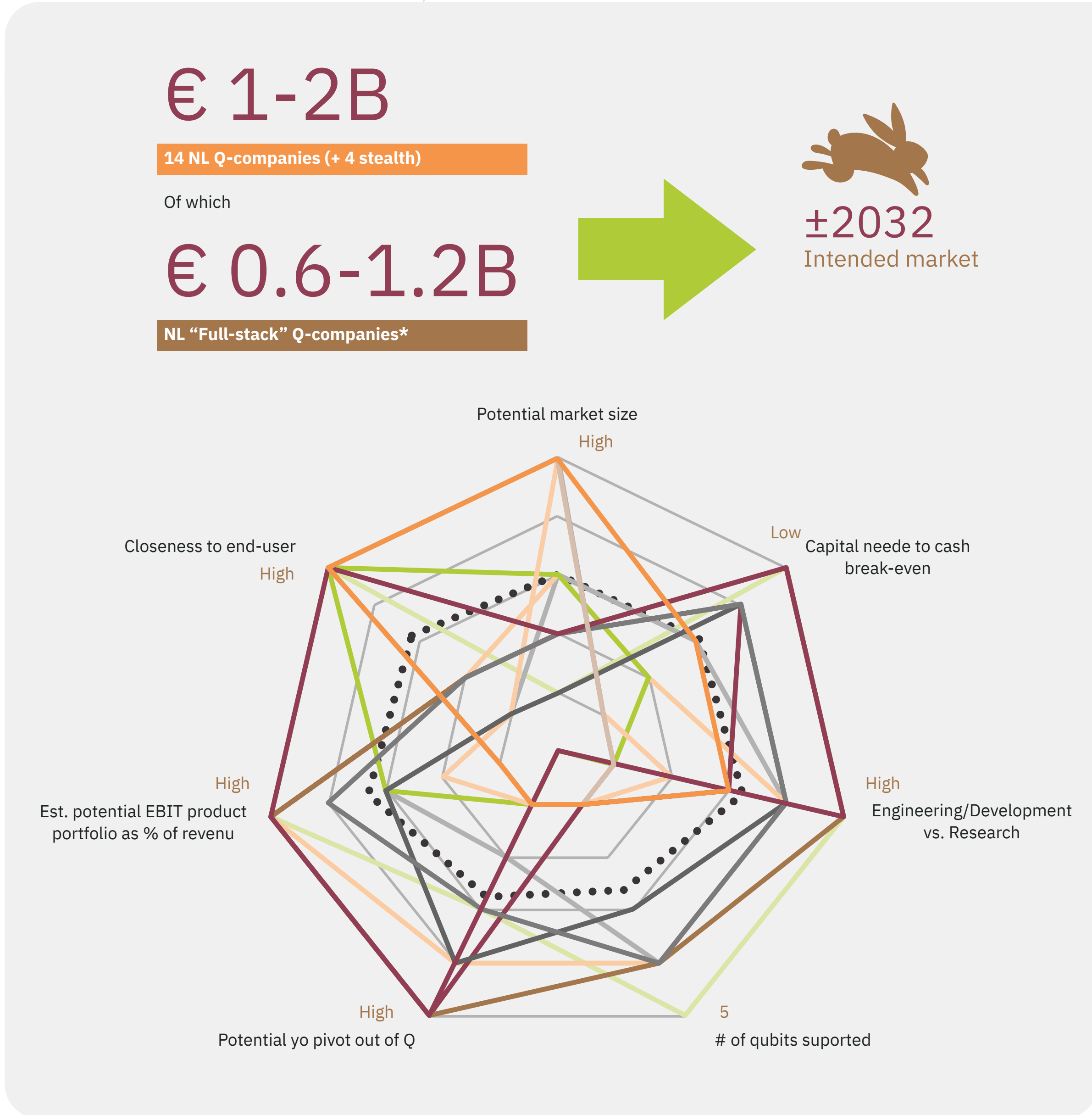
Roughly half would be required by full-stack players (in Computing and Communications). €150-300M is expected to be required in the next 1-1.5 years

Capital requirement is mostly driven by R&D. The ratio between required capital for R&D and estimated revenues before the intended market is expected to be highest for Full-stack players.
Most component/equipment companies that already generate revenue (and are state-of-the-art internationally) still require capital in order maintain fast enough innovation speed to remain ahead (or some cases, to catch up) with international competition. They are very well positioned to maintain their innovation speed, due to their in-house expertise and (upstream) ecosystem. Of these companies, most project that it can maintain its competitive position on or ahead of the development curve of the LSQC, and in doing so, they are very well positioned to become profitable after (and in some cases before) economic industrial scale is realized.

Other notable observations:

- 1 Dutch start-up in Quantum computing software, Qu&Co, has merged into the Quantum Computer start-up "Pasqal" from France;
- The vast majority of start-ups already have paying customers. Most still require additional capital to maintain innovation speed and competitive position globally in developing towards their intended market & cash break-even;
- At least 1 Dutch start-up already has a paying Industry end-user;
- The required capital by Dutch Quantum start-ups varies from 0 to 300 M (as stated by the companies themselves): there is a positive correlation between ratio Research vs. Development/Engineering and capital required;
- Almost all component/equipment companies can serve Quantum Computing companies with several types of qubits, which decreases the risk for investment wrt what qubit type could become dominant in Computing, and;
- Only some companies could pivot out of serving Quantum Technology customers if they’d want/need to.

This is a factor 1.5 – 2 higher than the Entrepreneurs’ assessment €700-1100M based on experience Deep Tech investors



Radar chart plotting selected Dutch Quantum Technology start-ups: though there is spread over most dimensions, R&D capital is required across the board to remain competitive and reach the intended market at relevant (innovation) speed

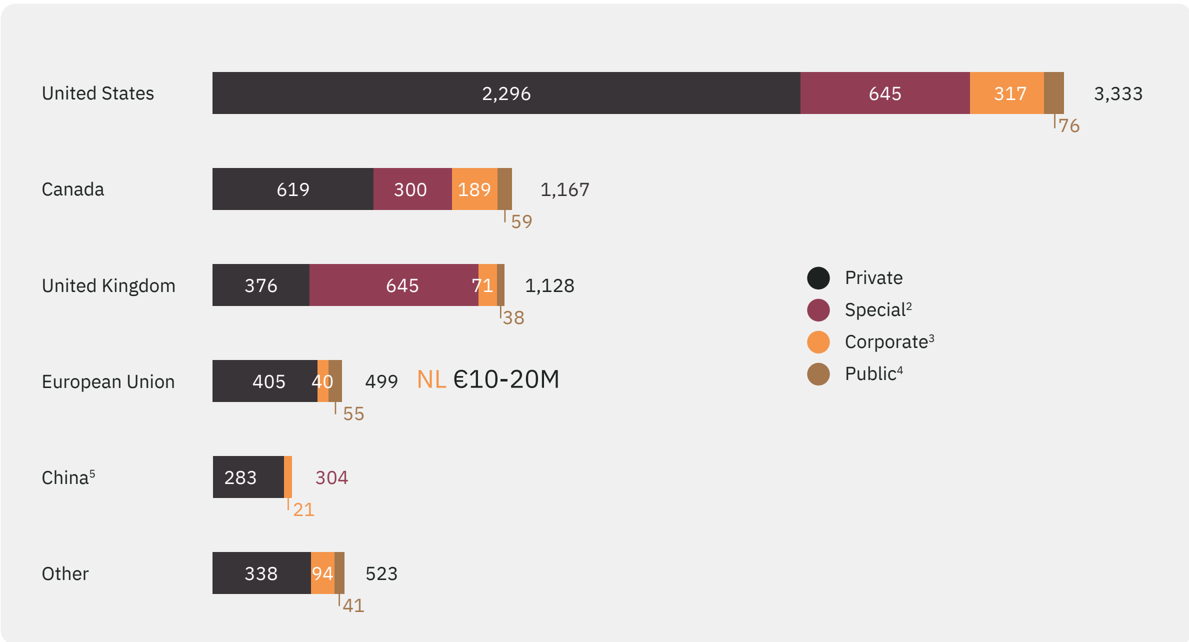
Private investment in Quantum Tech highest in US, Canada and UK, while opportunity in Netherlands is growing

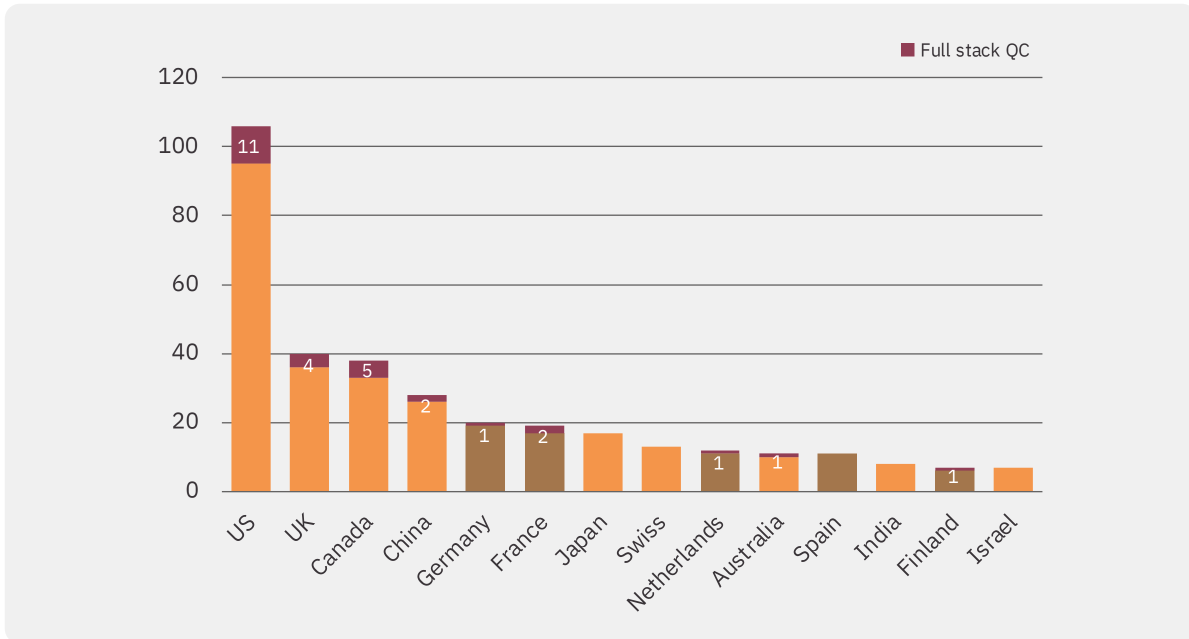
Most of the (private) investments into Quantum Technology is in the US.
From interviews it seems the Netherlands (not shown in the graph) has seen roughly €10 million in private investment in quantum start-ups, ±60 times less than Canada (as a comparible peer in terms of size and strength upstream eco system).

Nevertheless, in certain international rankings, the Netherlands typically holds a position between 6th and 8th concerning number of Quantum Technology/Computing start-ups, a number projected to more than double within the next two years.

In most cases these companies have been running on a mix of subsidies, sales to academic groups, seed funding from their nascent University/Institute, in some cases seed funding from Quantum Delta Participations, EIF/EIC, and/or Infinity QD.
A few have been able to raise capital from VC.

Total investment in qt-start-ups by location and primary investor type, 2001-2, $ million[1]





1. Based on PitchBook data. Actual investment volume in QTs is likely higher. Figures may not sum to totals, because of rounding.
2. Includes SPACs (eg, Rigetti Computing) and other special deal types (eg, Honeywell's investment of $300 million in Quantinuum).
3. Includes investments from corporations and corporate venture capital in external start-ups; excludes corporate investments in internal QT programs.
4. Includes investments by governments, sovereign wealth funds, and universities.
5. Data availability on start-up investment in China is limited. The overview includes all publicly available data on China. While actual investment is likely higher, we think that at this stage most investment awarded by China is to research institutions; other estimates place total private investments closer to $615 million.

Most Quantum Technology start-ups (and full-stack Quantum Computing start-ups, which require most capital) are located in the US

Source: McKinsey Quantum Technology monitor Apr 2023, interviews

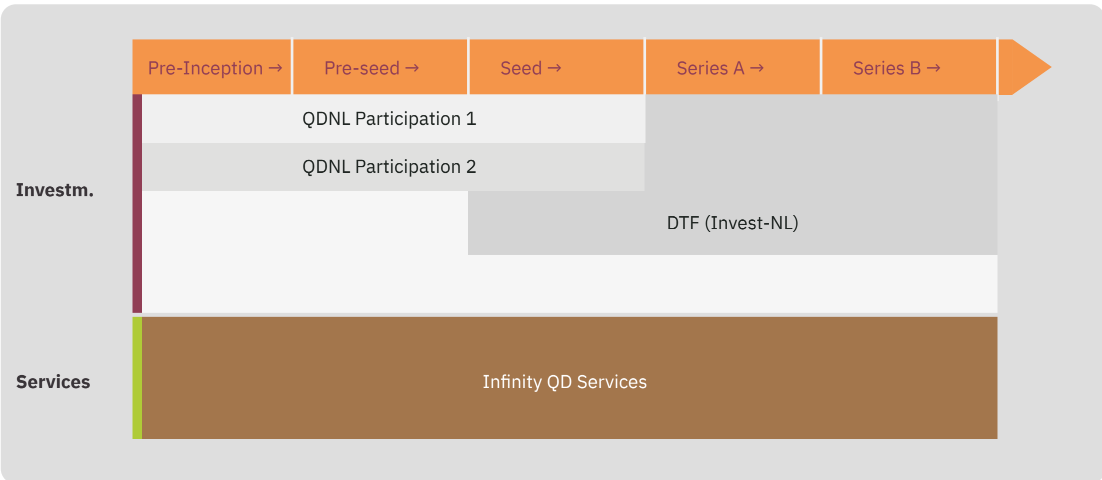
Most VCs dedicate only a portion of their funds towards Quantum, though dedicated VCs on the rise

There are several venture capital firms investing in Quantum Technology, each with its own area of expertise and committed funds. Few funds have more than 3 Quantum Technology investments.

In terms of Quantum Technology investment, Quantonation is in Europe currently the only Fund dedicated to Quantum Technology start-ups, its fund being €92M.

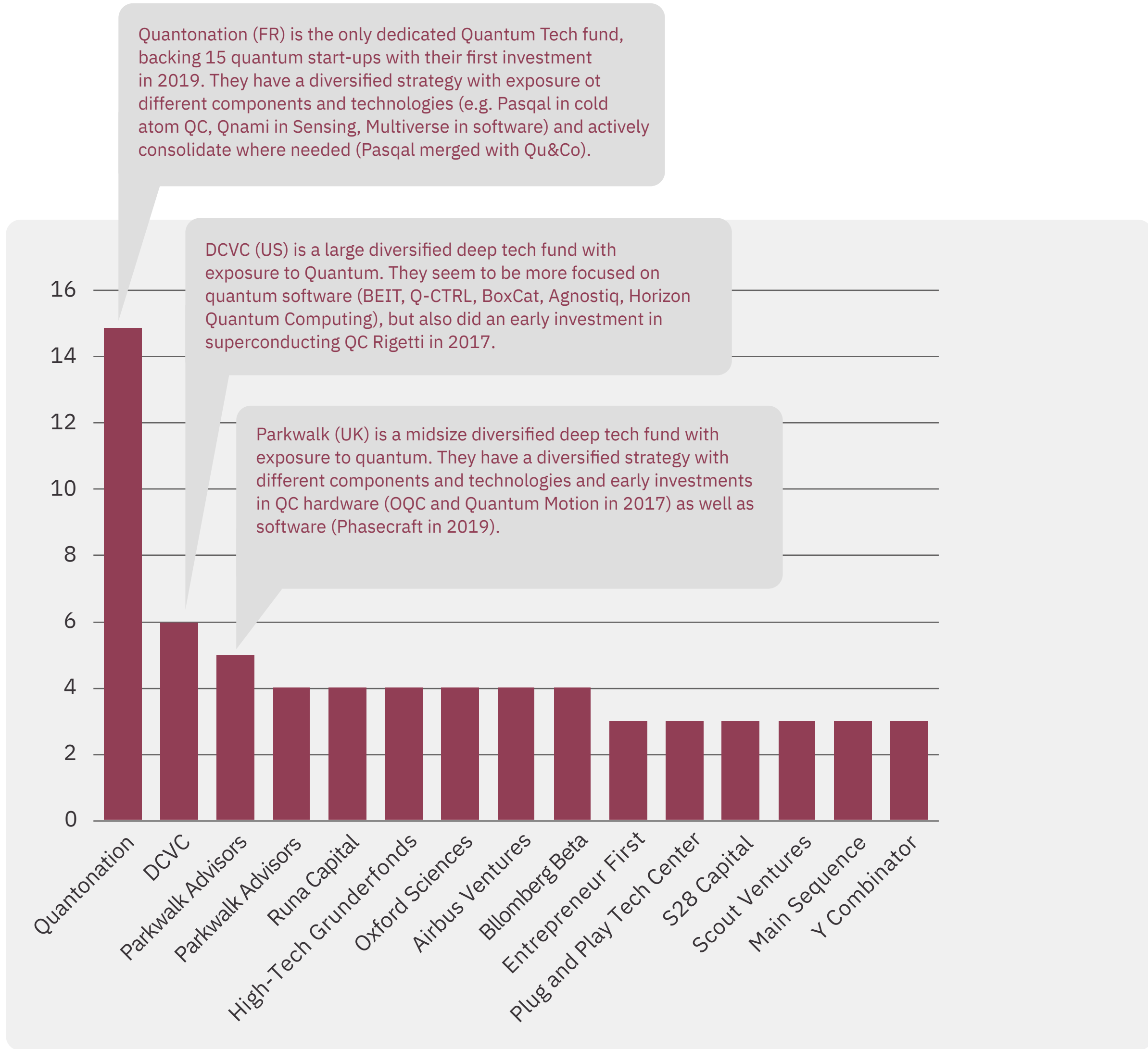
After the Quantum Delta Netherlands Participations 1 fund of €15M, aimed at (very) early stage Dutch Quantum Technology start-ups, Quantum Delta is in the process of creating a 2nd fund, significantly larger, also dedicated to Quantum Technology start-ups. This will be funded partly with public and partly with private funds.

Hereby there will be 3 Funds with (partly) public funding that invest, alongside of one antoher, in early stage Quantum Tech start-ups in the Netherlands.



QDNL Participations 1, 2, Invest-NL's Deep Tech Fonds and Infinity QD supports Quantum Technology start-ups throughout the early stages of their journey

# of Quantum start-up investments



Quantonation stands out in terms of # of Quantum Technology investment, being wholly focused on Quantum Technology start-ups. Quantum Delta is in the process of creating a similar Fund, significantly larger than its first €15M Fund, both also wholly focused on Quantum Technology.

Graph is not exhaustive.

Source: Innovation Industries, april 2023
Source: Innovation Industries, May 2023; Runa Capital, Crunchbase, Pitchbook

And what'll the DTF focus on?

Courtesy of QuiX Quantum

Impact & criticality in eco-system important factors investment decision DTF, full stack players scoring high on both

Quantum Investment strategy Invest-NL Deep Tech Fonds

The Invest-NL Deep Tech Fonds (DTF) aims **to strengthen the Deep Tech ecosystem** in the Netherlands by co-investing with private investors in early stage start-ups. Within the scope of Deep Tech is also Quantum Technology, one of The Netherlands' Key Enabling Technologies. In this context', a study has be conducted to map out the Quantum Technology ecosystem in The Netherlands and formulate a Quantum Technology investment strategy for the Deep Tech Fonds.

- The DTF is open for investment proposals from Quantum Technology Start-ups in the Netherlands, as most Quantum start-ups so far fit well within the DTF's scope. The DTF will co-invest with other investors in those start-ups that are assessed as sufficiently attractive. It assesses the Quantum start-ups by a.o.:
  - business case, team, financials and other factors that are part of its standard DD and assessment process;
  - (global) competitive position, to what extent it is (globally) state-of-the-art and their ability to maintain or improve its competitive position;
- In addition, the DTF assesses the start-up on "impact" on the eco system and/or "criticality" in the Quantum value chain (i.e. for a: Quantum computer, scalable QKD/Quantum Internet network, Sensing solutions), noting that typically:
  - full stack players in Computing and Communications typically score relatively high on both
  - components/equipment companies that are critical for scaling of Computing/Communication/Sensing solutions, score high on criticality;
  - scoring of players in Sensing depend on the Sensing application;
  - factors that are considered in impact a.o.: interdependency of other players in the eco system, # of Quantum engineers, revenue, overall size, business case.

Main considerations for strategy:

General:
- Quantum has been categorized as one of the Key Enabling Technologies (KETs) in The Netherlands and most Quantum Technology companies fit in the Deep Tech Fonds' scope, most notably because of the:
- Relatively long time to intended market, and;
- Multiple 10s of millions of capital required to get to market.

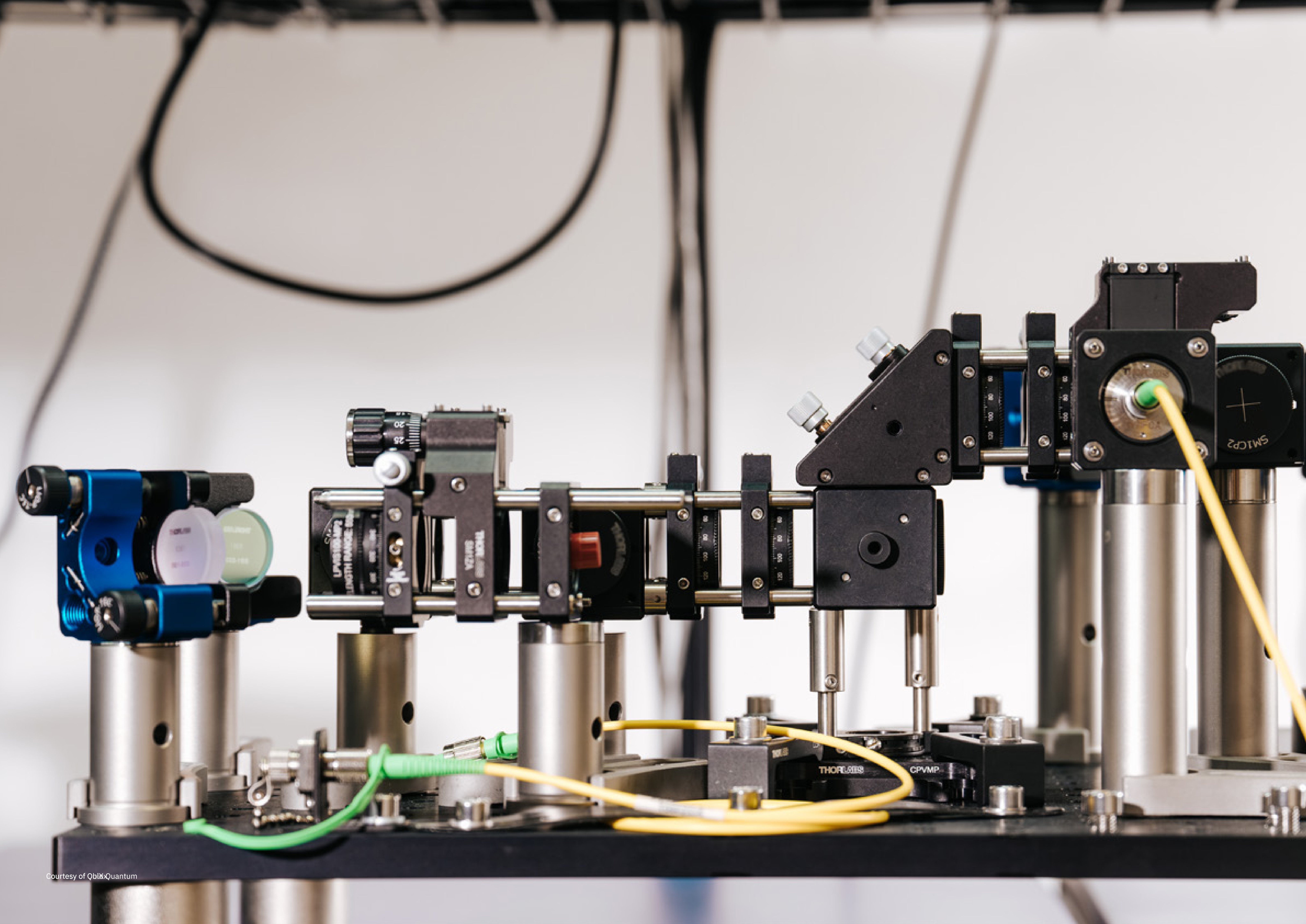
Computing:
- Even with advancements in classical computing algorithms, Shor & Grover's algorithm run on a sufficiently large scale Quantum computer will remain exponentially faster. It is expected that by 2030-2032 a Quantum computer is at relevant industrial scale at 100-400 logical qubits, dependent on advancements in classical computing. Classical computers & algorithms will continue to advance, but its advancement will eventually be caught up by Quantum computer development;
- Most widely adopted view among those interviewed with broad access and an understanding of the various technologies is that up to multiple dominant players per qubit type can coexist, over multiple qubit types (2-5), because of the pros & cons and complementarity different qubit types. Geopolitical tensions and less open markets are expected to increase these numbers of players;
- Both Full-stack players and component/equipment companies will be able to generate revenue before they hit their intended markets*, however ratio of revenues vs. required R&D capital expected to remain more favourable for component/equipment companies before intended market;
- In the value chain, full-stack players are expected to need most (R&D) capital to develop towards their intended market, have longer timelines, but are also expected to have an outsized impact on the ecosystem, because they drive the tech roadmaps of (local) suppliers (= upstream) and (technical) requirements & boundary conditions for applications/services (= downstream). In additions they're expected to have relatively highest revenue potential, because of their closeness to end users;
- Characteristics contributing to Equipment/component companies' attractiveness for investment include:
  - criticality of their product for scaling of the Computing/Communication/Sensing solution it serves, and advantage over alternatives (competition and/or "developing it yourself" by full stack players themselves);
  - less research-risk on tech roadmaps;
  - more favourable ratio of revenue from current product portfolio vs. required R&D capital towards intended market;
  - shorter timelines to revenue;
  - (In computing): ability to pivot between qubit types (most cases) and in some cases out pivot out of Quantum.
- In a "Quantum winter" and/or consolidation of Quantum equipment companies, full-stack players are expected to be dominant in driving consolidation (decisions);

Sensing:
- Most near-field, though market is also most niche compared to Computing and Communications, and;
- Sensing companies' applications is critical for its business case and market potential, as are its impact and criticality on/in ecosystem.

Communication:
- For QKD and Quantum communication several standards and protocols are in development. There are efforts for standardization across different countries. Which standards and protocols will prevail remains to be seen;
- Netherlands has strong upstream Quantum Communication capabilities (top tier globally), and (infrastructural) programs in place that can help accelerate development. From a technology and eco-system perspective a good (international) starting point, both for QKD and Quantum internet;
- QKD market is already generating revenues and expected to keep growing, though it remains to be seen how profitability will develop. Quantum communication/internet has more risk, longer timelines, but can turn out to be bigger dependent on the proliferation and success of Quantum Computers.

1. (Fundamental) Quantum start-ups in this report fall into 2 categories. 1) Quantum Computing/Communication/Sensing companies: their products/services rely on exploitation Quantum mechanical properties/dynamics to outperform "classical" counterparts (that don't exploit these properties/dynamics) in terms functionality and/or performance. 2) companies that make components for category 1) which are A) critical in the roadmaps and performance of category 1's technology, and; B) do not have an alternative technological solution (yet).

*intended markets. For Computing this is a LSQC at economic industrial scale, for Communications a scalable QKD a network and/or scalable Quantum communication network for Quantum computers



Courtesy of Qblox Quantum

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