IonQ, Inc. (IONQ)

Trapped in the Hype

We are short shares of IonQ, a $5 billion quantum computing company whose stock has tripled in recent months as retail investors, chasing the "next AI" trade, piled into an industry that has long been plagued by overpromises and hype. Despite retreating from all-time highs, shares still trade at a staggering 40x consensus 2026E revenue – a valuation that defies both logic and the warnings of former IonQ employees, who highlighted monumental scaling challenges that will derail the company's ambitious plans. We believe IonQ is far from being on the verge of a new era of commercial success with its limited, error-prone systems. Instead, investors seduced by IonQ's claimed "history of delivering on technical and commercial milestones" are fixated on relatively immaterial past achievements, while ignoring the existential challenge all early-stage computing companies face: scalability.

IonQ has painted a picture of exponential growth, forecasting a leap from ~80-100 physical qubits today to over 4,000 by 2026 and 32,000 by 2028. To achieve this, the company is banking on photonic interconnects to link its trapped-ion computing modules. Yet, despite over a decade of research and development, commercially viable photonic interconnects remain a distant prospect. IonQ has not been fully transparent with investors about the status of its photonic interconnect development, never disclosing performance metrics for this critical technology. However, recent data from the academic labs IonQ relies on for R&D reveal continued inefficiencies and abysmally slow speeds. A year ago, IonQ claimed it was "on track to finish" developing photonic interconnects by 2024, but industry executives we consulted confirmed that performance remains far below the threshold necessary for commercial scaling. Rather than reflecting a strategic shift, the looming inability to deliver on growth promises is what has driven IonQ's recent pivot into quantum networking, the need to raise additional equity despite prior assurances to the contrary, and other material changes to its technology benchmarks, financial reporting, and management, as announced late last month.

IonQ's lack of transparency is hardly new and widely recognized within the industry. Recently departed CEO Peter Chapman had a history of making bold claims that diverged from reality. In October 2020, Chapman claimed to have a system with "32 perfect qubits" when a former IonQ executive confirmed to us the company only had an 11-qubit machine at the time. That same year, Chapman also predicted IonQ would develop desktop quantum computers and achieve "broad quantum advantage across a wide variety of use cases" by 2025. Experts we spoke with viewed IonQ's assertion that its Tempo system will represent a "ChatGPT moment" as similarly outlandish – the device will instead be a "toy" incapable of providing meaningful commercial value. Throughout our research, we encountered consistent concern from experts about the gap between IonQ's market reputation and its standing within the industry as a purveyor of hype.

A cash-burning, highly promotional company in a hot sector valued at absurd revenue multiples, with retail investors piling in and ignoring critical scaling challenge – even as the CEO unloads *$37m* worth of stock – are hallmarks of a disaster in the making. Quantum computing may hold transformative potential someday, but the path is long, uncertain, and fiercely competitive with better-resourced players (both in quantum and classical computing) vying for dominance. Based on our research, IonQ is not even the clear leader among ion trap-based quantum computing providers. As reality sets in, IonQ shareholders chasing a quantum leap will find themselves wishing they had stayed in a more stable state.

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Executive Summary

IonQ has a massive scaling problem. For years, IonQ has projected it would produce systems with an exponential increase in physical qubits, from ~80-100 by the end of this year to a staggering 32,000 by 2028. To achieve this, the company plans to link multiple modules or cores – each containing roughly 100-200 qubits – using photonic interconnects, a technology that relies on photons and fiber optics to enable scaled communication between qubits. IonQ has provided only superficial descriptions of the milestones needed for photonic interconnect development and has been notably opaque about current performance metrics for this critical component. We suspect this lack of transparency stems from the interconnects' poor quality, which a CEO in the industry described as "absolutely appalling." Recent research from the academic institutions IonQ relies on for R&D reveals a stark reality: despite years of effort by scientists and engineers, the connection rates of photonic interconnects remain far too slow and inefficient to support scalable quantum computing. Experts we consulted confirmed IonQ is nowhere near "on track to finish" developing photonic interconnects, as the company claimed just last year. On its 4Q24 call, IonQ unexpectedly announced changes to its technology roadmap would be forthcoming and a key benchmark would no longer be used. We believe these changes obfuscate the nature of technical challenges that undermine IonQ's ability to deliver on ambitious promises.

Without a timely path to scalability, IonQ had been forced to pivot. IonQ lacks the vast financial resources and engineering capabilities of mega-cap competitors like Microsoft and Google, both of which have made significant commitments to quantum computing through internal projects and strategic investments in IonQ's direct competitors, such as QuEra, Quantum Circuits, Inc., Quantinuum, and PsiQuantum. While these competitors also face unresolved scaling issues, they benefit from substantial private funding and are pursuing promising alternative technologies and scaling methods that diverge from IonQ's approach – all without the distraction of appeasing shareholders with quarterly performance. With photonic interconnect development stalled and the path to profitability delayed, IonQ has raised additional equity, pursued interim sources of revenue though dilutive M&A, and will soon overhaul its technology roadmap. Investors buying in the IonQ story at this particular juncture are buying into a broken investment thesis.

A history of hype and misleading marketing. IonQ positions itself as "leading the pack" with a significant technological edge over competitors. However, based on over 20 interviews with industry participants (including former IonQ employees), the company excels more in promotional hype than in genuine technology leadership. For example, in October 2020, CEO Peter Chapman proudly unveiled a system with "32 perfect qubits," a claim that garnered significant attention. Yet, IonQ's own public filings over a year later described such a device as unavailable for customers. A former IonQ executive confirmed to us that the company only had an 11-qubit machine at the time. That same year, Chapman made a series of bold predictions, including the development of "modular, rack-mounted" computers, the ability to mass-produce quantum chips by simply instructing a manufacturer in Taiwan to "give me 10,000 [chips]" by 2023, and the achievement of "broad quantum advantage across a wide variety of use cases" by 2025. The same former IonQ executive viewed IonQ's nearly $1bn in revenue by 2030 as similarly unrealistic.

Shares have a long way to fall. While shares have dropped from recent highs, they remain up 300% since retail investors began flocking to quantum computing as the "next big thing." Even after the pullback, IonQ trades at a staggering 43x our estimated 2027 revenue. As momentum fades for cash-burning speculative bets, we expect IonQ's shares to continue their descent toward a fair value in the single digits.

Company Overview

Capitalization and Financial Summary

$ Millions, Balances as of Dec. 30, 2024	
IONQ share price	$22.00
Fully-diluted shares [1]	264
Market capitalization	**$5,818**
Operating lease liabilities	18
Cash and investments [2]	724
Net debt (cash)	(706)
Total enterprise value	**$5,113**

Financial Summary ($ mm)					
Fiscal year end Dec 31,	**2023A**	**2024A**	**2025E [3]**	**2026E**	**2027E**
Revenue					
Specialized hardware	9	22	43	73	80
Platform, consulting and other services	13	21	35	45	60
Total revenue	$22	$43	$78	$118	$140
Growth y/y	*98%*	*95%*	*81%*	*51%*	*19%*
Cash operating costs					
Cost of revenue	8	16	33	46	53
Margin	*37%*	*37%*	*42%*	*39%*	*38%*
Research & Development	52	78	100	112	120
Margin	*237%*	*181%*	*128%*	*95%*	*86%*
SG&A	42	56	73	80	86
Margin	*191%*	*130%*	*93%*	*68%*	*61%*
Adj. EBITDA loss (reported)	(80)	(107)	(128)	(120)	(118)
Stock-based compensation	(70)	(107)	(120)	(129)	(137)
Adj. EBITDA (incl. SBC)	(150)	(214)	(248)	(249)	(255)
Capex	(14)	(18)	(30)	(30)	(30)
Free cash flow (Adj. EBITDA less capex)	(94)	(125)	(158)	(150)	(148)
Key Metrics					
Enterprise Value / Sales		119x	66x	43x	37x

Source: Kerrisdale forecast. Historical financials per IonQ SEC filings.

1. *219.8m common shares outstanding as of February 19, 2025 pro forma for: 1) 23m net dilutive effect of in-the-money employee stock options and unvested restricted stock units using the treasury stock method, 2) 16m shares sold in recently completed ATM equity offering, 3)5.2m shares for acquisition of controlling stake of IQ Quantique SA (F-36).*
2. *Pro forma net aggregate proceeds of $360m from ATM equity offering.*
3. *2025E revenue and reported adjusted EBITDA in line with IonQ guidance. Note, IonQ's full year revenue outlook of $75m - $95m is back-half weighted (1Q25 is guided to between $7m and $8m) and includes an undisclosed inorganic contribution from acquisition of IQ Quantique, scheduled to close in the next nine months.*

Memo: A primer on quantum computing is beyond the intent and scope of this report. We would refer investors seeking a greater understanding of the underlying technology to initiating coverage pieces from Goldman Sachs (November 21, 2021) and Needham's "An Introduction to Quantum Computing and its Participants" (June 7, 2022). The online book, Introduction to Quantum Computing for Business is also a helpful resource. A summary of the basic differences between quantum computing and classical, as well as some common misconceptions, is provided in Appendix I.

Co-founded in 2015 by Dr. Christopher Monroe (former Chief Science Officer) and Dr. Jungsang Kim (former CTO), IonQ is a quantum computing company which specializes in trapped-ion qubits as the foundation for its quantum computers. Monroe and Kim pioneered research in quantum computing and its potential commercial applications in the 1990s, and their work at the University of Maryland and Duke University forms the backbone of IonQ's technology. Both founders stepped away from their day-to-day roles with the company in late 2023 and early 2024 to focus on academic pursuits. IonQ maintains exclusive license agreements to certain patents and IP related to trapped-ion quantum computing systems developed at Duke University. IonQ went public in 2021 through a SPAC merger and is headquartered in College

Park, Maryland, with additional with manufacturing and engineering facilities in Seattle, Washington. Last month, in conjunction with 4Q24 earnings, IonQ announced a management shuffle, with CEO Peter Chapman assuming the role of Executive Chair and board member, and Niccolo de Masi appointed as new President and CEO, effective immediately.

Methods of implementing qubits – known as modalities – vary widely across the quantum computing industry, each with its own set of advantages and disadvantages in terms of performance and scalability. Like other ion trap-based and neutral atom companies, IonQ uses "perfect," naturally occurring qubits, which benefit from high fidelity, the ability to operate at room temperature, and long coherence times. However, what nature provides in quality, it lacks in commercial practicality: trapped-ion qubits suffer from orders-of-magnitude slower gate speeds compared to semiconductor-based qubits, as well as significant scaling challenges due to the complexity of controlling and interconnecting large numbers of ions. For a deeper dive into how ion traps work, please see Appendix II, and for an overview of leading modalities and their respective performance characteristics, refer to Appendix III.

Despite hyperbolic claims that quantum computing will "CHANGE everything!," quantum computing is not simply a faster version of classical computing. It will not revolutionize every industry, nor will it replace traditional computers for everyday tasks like browsing the internet, streaming Netflix, or gaming. IonQ, like others in the industry, believes quantum computers have the potential to address specific problems that classical computing may never solve, with applications in simulating quantum systems (e.g., in materials science or pharmaceuticals), factoring large numbers for decryption, and solving complex optimization problems. Many of these problems, however, require far more stable qubits and higher fidelity than what is currently achievable.

Today, quantum computing companies generally possess systems with anywhere from 30-1,000 physical qubits, depending on hardware approach. Yet experts estimate that millions of qubits – alongside significant advancements in algorithmics, software, and cryogenic cooling systems – will be necessary to tackle challenges like complex molecular simulations or code-breaking using Shor's algorithm.

IonQ's most advanced system currently available, Forte Enterprise, boasts 36 physical qubits and 36 "algorithmic qubits" (#AQ).[1] The company is targeting the release of prototypes for its next-generation quantum computer, Tempo, with #AQ64, later this year. IonQ's website claims Tempo will be "capable of commercial advantage for certain applications," but experts we interviewed were skeptical, describing the device as little more than a "toy." We believe IonQ's strategy of pushing error-prone systems for commercial sales – systems which fall far short of true fault-tolerant quantum computing – is driven less by customer demand and more by the pressures of being a publicly traded company with substantial cash burn and unresolved scalability challenges. The true end goal for all quantum computing companies is to develop reliable, powerful systems that can outperform classical computers across a wide range of

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[1] Algorithmic qubit is an IonQ-invented, controversial benchmark used for marketing. IonQ defines algorithmic qubits as the number of "useful" qubits in a system, considering noise, connectivity limitations, and other sources of error. The metric depends heavily on the algorithm being run which complicates comparisons across different quantum computing platforms. Logical qubits are fault-tolerant qubits encoded using multiple physical qubits. Logical qubits is more widely used among industry peers like IBM, Google, and Quantinuum, when discussing scalability and reliability of their systems as it provides a clearer, more standardized measure of a quantum computer's capabilities, especially in the context of fault-tolerant quantum computing. We believe in light of the benchmark's flaws and lack of adoption, on the company's most recent earnings call, IonQ management stated it would "deprecate" AQ as a measure of technical progress going forward in favor of still undisclosed new metrics.

applications – not just achieving narrow, vaguely defined "commercial advantage." Until then, we view IonQ's efforts to monetize its current capabilities as premature and opportunistic, rather than grounded in meaningful technological progress.

Industry experts often characterize the path to quantum advantage as being solved in three phases (IonQ Form 10-K, p.7):

- Noisy and intermediate-scale quantum (NISQ) computers: The earliest stage of development. Error-prone, intermediate-scale systems used for developing new quantum approaches with limited commercial applications and not expected to generate substantial revenue.
- Broad quantum advantage: Quantum computers expected to offer practical solutions to meaningful problems superior to those provided by classical computers, providing a genuine commercial impact.
- Fault-tolerant quantum computing: Large modular computers with enough power to tackle a wide array of commercial applications to many sectors of the economy. Classical computers no longer compete with quantum computers in many fields.

Value Creation in the NISQ Era Has Been a Disappointment

IonQ's aspiration to deliver "commercial advantage" with a #AQ64 system arrives against the backdrop of an industry that has repeatedly failed to live up to its own hyped promises. As theoretical physicist and frequent quantum computing industry commentator Sabine Hossenfelder recently observed, "it's been a recurring story that we have seen numerous times in the past years, that claims of quantum 'utility' or quantum 'advantage' or quantum 'supremacy' or whatever you want to call it later evaporate because some other group finds a clever way to do it on a conventional computer after all."

Last year, consulting firm BCG acknowledged that advancements in quantum hardware and software had fallen well short of expectations, while competition from classical computing – particularly from AI – had been more formidable than anticipated. As a result, BCG revised *down* its estimates for near-term value creation in the current NISQ era.

As BCG explains:

> *"…with existing software, most valuable use cases require **10,000 to 20,000 qubit-gate operations** and close to 100% gate fidelity, but circuits of more than 30 qubits have so far achieved at best a 99.5% fidelity rate (a barrier that was only partially broken in April 2024 when collaborative efforts by Microsoft and Quantinuum on their H1 systems reached a "three nines" rate for 2-qubit gates)...Useful algorithms need millions of gate operations (even billions in the case of Shor's algorithm), so **quantum machines still need to improve by many orders of magnitude."*** [emphasis added]

The shortfalls have not only been on the quantum hardware side. The report also notes the complete lack of meaningful quantum algorithmic development, stating that "little progress has occurred in the past ten years." Against this backdrop, IonQ's claims of imminent commercial advantage appear even more tenuous.

History of Exaggerated Claims

A recurring theme encountered during our research was IonQ's tendency to make overly optimistic predictions, exaggerate the significance of announcements, and present misleading comparisons of its technology versus competitors' (details of which are explored later in the report). Some of this behavior was well-documented in a report from Scorpion Capital, which highlighted the company's 2020 unveiling of a system with "32 perfect qubits." This is contradicted by IonQ's own public filings over a year afterward which describe such a device as unavailable for customers. Interviews we conducted with a former IonQ employee confirm IonQ only had an 11-qubit machine at the time.

In 2020, CEO Peter Chapman also laid out a series of ambitious goals, including doubling or more than doubling the number of qubits each year, selling "modular, rack-mounted" computers by 2023, and having the capability to mass-produce quantum chips by simply instructing a manufacturer in Taiwan to "give me 10,000 [chips]" by the same year. Chapman also predicted that IonQ would develop desktop quantum computers and achieve "broad quantum advantage across a wide variety of use cases" by this year. These claims, while attention-grabbing, have proven to be wildly optimistic.

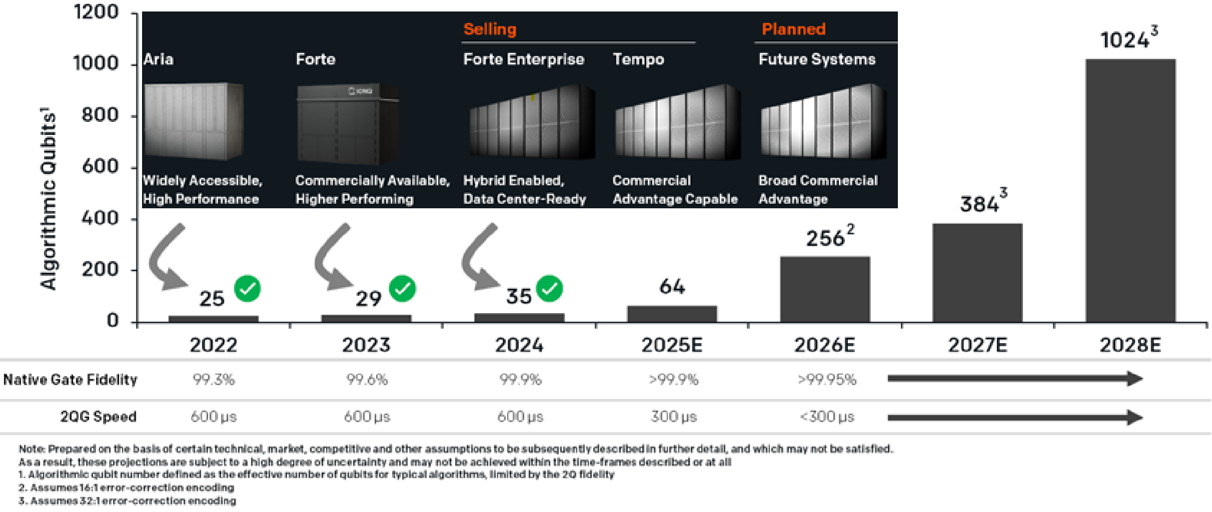
According to individuals familiar with the company's internal dynamics, this culture of overpromising and excessive promotion played a role in the departure of co-founder Dr. Chris Monroe and other key executives, including Dave Bacon – a highly regarded quantum computer scientist known for his work on the Bacon-Shor code – whose tenure at IonQ was notably brief.

Shifting Technology Roadmap

IonQ believes its system could enable breakthroughs in areas like building better batteries for electric vehicles with #AQ ~250 and improving drug discovery with #AQ ~1,000. These milestones have been part of the company's broader goal of reaching #AQ1,024 by 2028 (see below), a target that had been a consistent feature in investor presentations for several years (p. 27). However, in its most recent 4Q24 earnings presentation, IonQ unexpectedly removed this roadmap chart, with management stating on the call that an updated computing and networking roadmap would soon be provided. This new roadmap would also "deprecate" the algorithmic qubit benchmark in favor of new metrics, signaling a significant shift in how the company measures and communicates its progress.

To scale beyond ~200-300 physical qubits (p.19), IonQ plans to connect modular quantum processing units (QPUs) using photonic interconnects – a technology that remains unproven at the required scale (more on this shortly). As recently as last November (p.12), IonQ aimed to achieve #AQ256 in 2026. The recently announced change coupled with the abandonment of previously relied upon benchmarks raises serious questions about the feasibility of this target.

IonQ’s (Now Scrapped?) Technology Roadmap / Product Portfolio



	2022	2023	2024	2025E	2026E	2027E	2028E
Native Gate Fidelity	99.3%	99.6%	99.9%	>99.9%	>99.95%	→	→
2QG Speed	600 µs	600 µs	600 µs	300 µs	<300 µs	→	→

Note: Prepared on the basis of certain technical, market, competitive and other assumptions to be subsequently described in further detail, and which may not be satisfied. As a result, these projections are subject to a high degree of uncertainty and may not be achieved within the time-frames described or at all

1. Algorithmic qubit number defined as the effective number of qubits for typical algorithms, limited by the 2Q fidelity
2. Assumes 16:1 error-correction encoding
3. Assumes 32:1 error-correction encoding

Source: Kerrisdale chart which overlays IonQ’s technology roadmap with elements of its commercial product portfolio as found on pp. 11-12 of the company’s November 2024 Investor Presentation.

Financial Profile

> ***Kerrisdale**: Do you think [IonQ] will get to $1bn in revenue by 2030?*
>
> ***Former IonQ Executive**: **Hell no!** [laughs]…the largest revenue company right now is IBM and IBM is really struggling because the first adopters have adopted quantum and there aren’t a lot of new places doing quantum, so in other words, we haven’t convinced John Deere to do quantum or maybe any other top 100 companies, and **so there’s a lull and everybody’s desperate for business**, and it’s not until the computers become very significant in what they do that more people are going to adopt…**being at $1bn dollars is crazy.”***

Though not a young company, IonQ is still in the initial stages of commercial growth and has incurred significant operating losses since inception, with an accumulated deficit of $684m as of YE2024. In 2024, IonQ reported an adjusted EBITDA loss of $(107)m with Street forecasts for continued EBITDA losses through 2026 before inflecting positively in 2027. Pro forma the early termination of a $500m ATM equity offering, which raised $360m in net aggregate proceeds, IonQ has over $700m in cash on hand. Note, IonQ announced this dilutive capital raise despite previously stating it already had sufficient funds to reach profitability and nearly $1bn in revenue by 2030, based on its prior roadmap. We believe IonQ has encountered considerable, underappreciated challenges in scaling its systems resulting in a much longer path to commercial relevance. We assume much more modest topline growth versus consensus and continued negative cash burn throughout the projection period.

IonQ presently has four main sources of revenue: dedicated on-premise quantum computing hardware along with related maintenance and support, preferred compute agreements/private direct access to IonQ owned quantum computers, partner/public cloud access via AWS Bracket, Microsoft Azure Quantum and Google’s Cloud Marketplace (“QCaas”), and application co-development professional services. IonQ does not provide a detailed breakdown of revenue by source, only reporting specialized quantum computing hardware (50% of 2024 total revenue) and platform, consulting and support services. At its 2023 analyst day, IonQ stated revenue from cloud partners was the smallest of its revenue groups. According to an IonQ partner we spoke with, access to IonQ's quantum computers is unreliable, with the machines more frequently offline than any other on the AWS Bracket platform.

IonQ revenue has historically been highly concentrated among a select set of partners (University of Maryland, Air Force Research Lab, QuantumBasel, U.S. Government agencies). For the year ended December 31, 2024, IonQ had two significant customers that accounted for 77% of total revenue, up from 58% in 2023. This growing concentration underscores the stagnation in customer breadth as described by the former IonQ executive quoted at the beginning of the section.

Recent Events

> *"**IonQ is utterly absurd**…and now I need to make sure I only share public stuff, but if you look at the quality of the qubits, and IonQ has improved tremendously over the past few years, but I don't think it's enough to power [anything special]…**there's no fundamental reason to believe that IonQ is worth [$9bn] or even half of that."** [emphasis added]*
>
> — Chair of leading quantum computing market intelligence provider and industry group
>
> ***Former IonQ Executive:*** *"**ID Quantique is not that great** and so I view it as something they picked up as a bargain, and I don't view it as something very strategic except they're trying to broaden their offering and perhaps work their way in [to new customers] through ID Quantique or other acquisitions - **it's just, they're not making it in quantum computing**.[emphasis added]*
>
> ***Kerrisdale:*** *So, it's a defensive maneuver?*
>
> ***Former IonQ Executive****: It is.*

Quantum computing stocks have seen enormous gains over the past few months, fueled by a surge of interest from retail investors. Though off recent highs, IonQ shares remain up over 140% since last October, despite consensus revenue estimates that have stayed largely unchanged. Prior to this rally, IonQ traded at approximately 10x EV/2027E sales. Shares now trade at more than double that multiple and roughly 5x management's five-year forward revenue expectation of ~$1 billion in sales by 2030E. This valuation expansion comes despite a bevy of announcements from the company, which in our view, reflect significant scaling challenges within quantum computing. While financial results and outlook were generally in line with expectations, during its 4Q24 earnings call IonQ announced the following:

- **CEO Transition**: Peter Chapman has been replaced by board member Niccolo de Masi, with Chapman assuming a new role as Executive Chair.
- **Updated Roadmap**: The company's technology roadmap will soon be revised, with algorithmic qubits to no longer be relied upon as a benchmark.
- **Bookings Guidance Discontinued**: Bookings guidance will be eliminated as a measure of hitting commercial sales milestones.
- **ATM Equity Offering**: A new $500m ATM equity offering, though it was terminated early

after raising $360m in net proceeds.
- **Acquisition of ID Quantique**: A definitive agreement to acquire a majority stake in ID Quantique, a quantum networking provider (not a quantum computing company) using up to 5.2m in IonQ stock. The deal values ID Quantique at a rumored $250m, but according to a sellside analyst who covers IonQ, the company would not clarify that figure even offline, nor would the company confirm the exact percentage being acquired.
- **Back-half Weighted and Unclear Revenue Guidance**: 1Q25 revenue was guided to just $7-8m (a sequential decline from 4Q24 and flat to 1Q24), meaning full year 2025 guidance of $75-$95m is heavily weighted toward the second half of the year and is benefited by the anticipated contribution from the acquisition of ID Quantique which has not yet closed. Furthermore, management did not disclose the amount of inorganic revenue embedded in its outlook, leaving the true organic growth trajectory of the business unclear.

As one might expect, IonQ downplayed the significance of the management shuffle and emphasized the “synergies” between its newly acquired networking business and its core computing operations. However, according to the former IonQ executive quoted earlier, the acquisition was not particularly strategic at all, but rather “a way to bring in interim revenue” while the company continues to struggle with developing commercially viable photonic interconnects – a critical component needed to scale its systems. We believe it is a glaring red flag to investors that the terms of the ATM equity offering allowed former CEO Peter Chapman to sell up to 2.2m shares during the trading window between the end of the ATM program and March 14th (p. S-5). Then, despite the decline in shares following 4Q results, Chapman still took full advantage of the opportunity by selling $37m worth of stock at $18.72 (-15% below current).

Photonic Disconnects

> *“Later this year, we expect to show that we can connect multiple qubits together across QPUs and that those connected qubits can be used for distributed quantum computation.”*
>
> — CEO Peter Chapman, February 2024

> “We’re on track to finish the photonic interconnect this year.”
>
> — VP of Research & Development Pat Tang, February 2024

> ***“[Photonic interconnects] really aren’t working...people who need photonic interconnects – there’s no existing supply chain that can deliver the quality that they need****…IonQ very openly says we’re going to build lots of small modules or cores with 100-200 qubits and then connect them together using photonic interconnects and that way we can build a much bigger quantum computer.*
>
> *Photonic interconnects have been in the making for a super long time. IonQ’s founders,* ***Chris Monroe and Jungsang Kim, spent basically their academic lives trying to get photonic interconnects to work. And they’re really struggling.*** *The world is really struggling…* ***the quality of these [interconnects] is absolutely appalling*** *to the point that no one has demonstrated a photonic*

> *interconnect that is good enough for fault tolerant quantum computing yet, they're nowhere near that at the moment. [emphasis added]*
>
> — CEO of private quantum computing company

> *"Yeah, I don't think they're going to get there [#AQ256] in 2026, I don't think there's really any realistic way."*
>
> — Former IonQ physicist

We believe IonQ faces a monumental scaling problem that will necessitate a complete reset of its technology roadmap. A year ago, management claimed to be "on track to finish" photonic interconnects a year ago, but this prediction – much like Chapman's forecast of desktop quantum computers by 2025 – has derailed. The quality of the technology remains, as one industry CEO described to us, "appalling" and the pace of progress has disappointed researchers. To date, IonQ has only demonstrated two (p.31) of the four high-level milestones it has identified for photonic interconnect development, such as remote ion-ion entanglement. Equally concerning is IonQ's lack of transparency regarding performance metrics, such as photon collection efficiency and entanglement rates, which are critical to assessing the viability of its photonic interconnects.

In order for IonQ to scale exponentially beyond #AQ64 and hit #AQ256 in 2026, the company is relying on linking multiple QPUs with robust photonic interconnects (p.39). The Tempo #AQ64 system later this year is supported by 80-100 physical qubits. To reach #AQ256, assuming 16:1 error-correction as footnoted, the number of physical qubits jumps to *over 4,000.* And for IonQ to hit its goal of 1,024 error-corrected algorithmic qubits by 2028, the company would need to scale to an astonishing 32,000 physical qubits. The high-quality photonic interconnects needed to bridge this gap – 100 qubits to 32,000 in just three years – simply do not exist. Based on our research, they are unlikely to materialize soon enough to avoid a complete overhaul of IonQ's previously issued timeline.

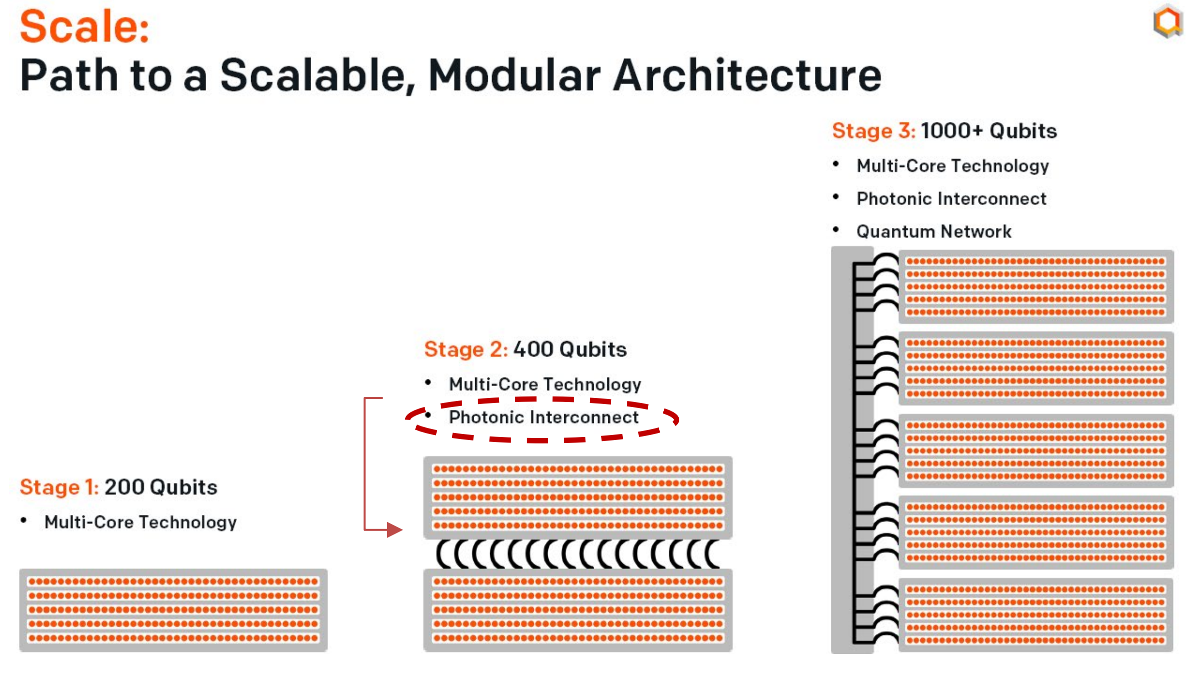
The (Blocked) Path to Scalable, Modular Architecture

Photonic interconnects are the linchpin of IonQ's scaling strategy. In a trapped-ion quantum computer, these interconnects function like fiber-optic highways, enabling separate groups of ions (qubits) to communicate with each other, even if they reside in different traps. Here is how it works: Each ion naturally emits photons (particles of light) when hit with a laser. These photons carry information about the ion's quantum state. By capturing and transmitting these photons through optical fibers, qubits in separate traps can be linked. When two photons from different traps meet at a beam splitter and interfere in precisely the right way, the two ions they came from become entangled – essentially "quantum-linked" – despite being physically separated.

This approach allows a trapped-ion quantum computer to scale beyond the constraints of a single trap. Rather than attempting to cram more ions into one trap (a process that becomes increasingly difficult to control), multiple smaller processors can be networked together using photonic links. In essence, the technique creates a system of interconnected smaller computers sidestepping the need to build one massive supercomputer.

As outlined in its investor presentation (see below), IonQ intends to use multiple cores to reach 200 physical qubits (Stage 1). To scale beyond this level and connect multiple cores, IonQ will use a series of photonic interconnects (Stage 2). To scale into the many thousands of qubits, IonQ intends to use a combination of photonic interconnects and quantum networking (Stage 3).

Path to Scalable, Modular Architecture Relies on High Quality Photonic Interconnects (That Do Not Currently Exist)



Scale:
Path to a Scalable, Modular Architecture

Stage 3: 1000+ Qubits
- Multi-Core Technology
- Photonic Interconnect
- Quantum Network

Stage 2: 400 Qubits
- Multi-Core Technology
- Photonic Interconnect

Stage 1: 200 Qubits
- Multi-Core Technology

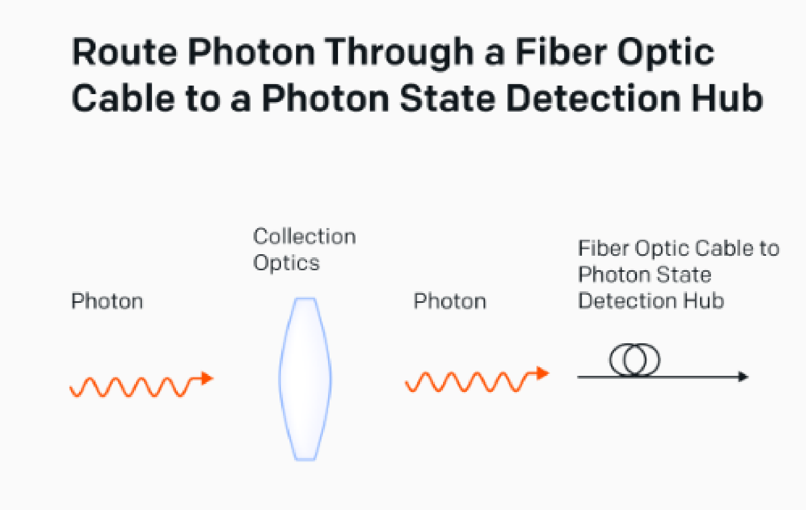
Source: IonQ November 2024 Investor Presentation.

While the concept may seem straightforward, making this system work reliably has proven to be an enormous technical challenge. According to industry experts, researchers have so far been able to collect and use effectively only a tiny fraction of the photons emitted, resulting in a system that is painfully slow – a particularly problematic issue for ion-trap based systems, which are already slower than other quantum computing modalities. Photons are frequently lost, misaligned, or fail to interfere properly when transported by fiber-optics, creating a system that is highly inefficient and "loss-y."

IonQ's lack of progress on photonic interconnects is evident in a July 2024 paper co-authored by IonQ founder Dr. Chris Monroe and scientists from the Duke Quantum Center and Joint Quantum Institute at the University of Maryland. The paper reveals that the current rate at which trapped-ion qubits can be entangled using photons is approximately 182 connections per second – a pace much slower than local connections made directly between ions within the same trap, which occur at 10,000 to 100,000 times per second. A key bottleneck is the exceptionally low success rate of each entanglement attempt, at just 0.0218% per attempt. This inefficiency stems largely from the fact that the lenses used to collect photons capture only about 10% of what is emitted. While placing ions inside special optical cavities can help photon collection by reflecting and focusing more photons, this setup requires further slowing down the process, reducing the entanglement rate to a glacial 0.43 entanglements per second (less than 1 Hz).

Experts we consulted emphasized that for photonic interconnects to be viable for scalable quantum computing, the entanglement rate would need to improve by four to five orders-of-magnitude – from 1 Hz to at least 10 kHz – while maintaining high fidelity. Achieving this level of performance will require many more years of research and development, effectively undermining IonQ's near-term objectives and jeopardizing its timeline to cash flow profitability. Despite the critical importance of photonic interconnects to IonQ' scaling plans, the company has provided investors with only superficial updates, such as blog posts about milestones and schematic diagrams (see below), rather than substantive updates on performance metrics.

Photonic Interconnects



Source: IonQ blog, February 22, 2024

According to a former IonQ employee, the company has tried to acquire companies with promising photonic interconnect capabilities to accelerate progress, but these efforts have either fallen through or failed to yield meaningful advancement (e.g., Entangled Networks). IonQ recently closed the acquisition of Qubitekk, a quantum networking company, but as SVP of Engineering & Technology Dean Kassman clarified on the 3Q24 call, the entanglement of two QPUs – essentially creating a photonic interconnect between two cores – is "not part of the fundamental technology stack that we have with Qubitekk." Kassman drew parallels and "analogies" between photonic interconnects and quantum networks, but this comparison is tenuous at best. This acquisition along with the acquisition of ID Quantique, while potentially beneficial in IonQ's longer-term quantum networking plans, does little to address the photonic interconnect challenges IonQ currently faces in scaling its quantum computing systems.

Signs of a Pivot

Four months after the Duke University study was published, IonQ's announced a renewed partnership with imec to develop photonic integrated circuits (PICs) and chip-scale ion trap technology. This move suggests, in our view, that the company is exploring parallel scaling paths and/or alternatives to photonic interconnects. According to industry experts consulted, better integration of photonic collection optics on a chip could help with the poor capture rate plaguing current systems. Additionally, if IonQ can increase the number of qubits per module using chip-scale ion traps, it might also be able to delay its reliance on interconnects altogether. If chip-scale ion traps can leverage microwave-based control – a technique employed by trapped-ion competitor, Oxford Ionics – or efficient on-chip ion shuttling, it could further reduce IonQ's dependence on the slow and inefficient photonic links which impede its scaling efforts.

The problem is none of this can come together quickly. Imec, a European semiconductor fabrication company, specializes in pre-production volume R&D chip fabrication, not off-theshelf solutions. IonQ cannot simply place an order for trapped-ion chips with integrated photonics and expect immediate results. Imec can fabricate what IonQ designs, but the process will require years of development and multiple iterative cycles, once again rendering the current roadmap impractical.

Quantum Hype

> *“**Their reputation within the quantum computing industry is that they lie. Their CEO says things that aren’t true.** They’re hyperbolic and not a good partner because they’re going to try and go after your customers.”*
>
> — Senior executive, leading provider of quantum consulting services and solutions company that partners with many quantum computing companies across the ecosystem
>
> *“I’ve been on the inside of many hype companies, and I know what’s going on. **IonQ is the #2 trapped-ion company, they’re not #1,** and the hype continues, but I will say that **Peter Chapman’s personality is lie, lie, lie** so I’m not surprised the company is running that way.”*
>
> — Former IonQ executive
>
> *“**This [#AQ64] is completely overhyped**...companies that claim they have utility today, its highly misleading I find, and they get really creative in how they define ‘utility.’” [emphasis added]*
>
> — CEO of privately held trapped-ion quantum computing company
>
> *Quantum computers that are “practically useful” are 5-10 years away.*
>
> — Sundar Pichai, CEO Google, World Governments Summit, Dubai February 12, 2025

[emphasis added for all]

While the quantum computing industry remains firmly in the NISQ era – with fully fault-tolerant, large-scale systems, likely several years if not over a decade away – IonQ’s strategy is to produce devices that could deliver near-term “commercial advantage.” Privately held competitor, Quantinuum, has estimated that 100 logical qubits are needed to achieve certain scientific advantages. Prior to going public, Chapman echoed this sentiment, stating that 80-150 high-fidelity qubits would be needed to derive quantum advantage. Yet, in 2025, starting with its Tempo generation of devices later this year, IonQ now claims it can deliver commercial value with just #AQ64.

A former senior executive at PsiQuantum urged skepticism towards IonQ’s claims. The current level of fidelity and qubit count, he explained, remain insufficient for running complex algorithms without accumulating errors that render the results unreliable. Instead, IonQ will need to break down problems into smaller, simpler algorithms, severely limiting the device’s utility. In practice, Tempo will likely serve as a tool for early adopters and quantum-curious companies to familiarize themselves with the technology, rather than solve problems of meaningful commercial value. In other words, the device will be used primarily like every other quantum hardware sale in the industry to date – for research and experimentation. As the CEO of a private quantum computing company bluntly put it, "The gap between the hardware and the applications is so large that effectively what you have is a bunch of toys." This assessment underscores the chasm between IonQ's aspirations and the current reality of quantum computing.

Recent Partnership Announcements Amount to Little

On IONQ's 3Q24 earnings call, Chapman described challenging his team to move beyond academic debates over quantum supremacy and instead focus on answering "a critical question": which application areas would first see quantum-enabled commercial advantage. His team identified biopharmaceutical drug discovery and computer-aided simulation for engineering and manufacturing – two fields long recognized by researchers as promising candidates for quantum practicality (amid likely "dead ends in the maze of applications" which won't see benefits anytime soon). Despite the lack of novelty in these findings, Chapman framed the identification of these two areas as a "seminal moment" for the quantum industry. He then enthusiastically announced new partnerships with pharmaceutical giant, AstraZeneca, and engineering and design software provider, Ansys.

While Chapman hailed the AstraZeneca partnership as "monumental," a former IonQ executive dismissed it as "not a big deal." In reality, the partnership amounts to AstraZeneca granting IonQ access to its BioVentureHub – a forum established years ago to foster innovation among ~25 startups in medtech and emerging life sciences. As the BioVenture Hub website describes, all participating companies operate independently, with AstraZeneca holding no ownership or innovation rights. The agreement carries no financial significance and falls far short of the high-level, tightly integrated collaboration Chapman's rhetoric might suggest. Even if it were such a collaboration, the practical impact would likely remain negligible for the foreseeable future.

The Ansys announcement is similarly vague and overstated. As the former IonQ employee pointed out, there is no straightforward way to take Ansys' engineering simulation software and "poof" translate it into a quantum algorithm that delivers superior results compared to classical systems. Ansys' proprietary software would need to be entirely rewritten. As noted physicist and quantum computing expert Scott Aaronson has argued, the most promising applications of quantum computing are believed to be in the simulation of quantum mechanics and cryptography. Other areas, such as machine learning and finance, where speed-ups have been proposed and significant sums invested, are classical problems with no inherent connection to quantum mechanics. The value proposition in these fields remains "much iffier," as Aaronson put it. In our view, the Ansys announcement is little more than a marketing exercise, offering no tangible financial benefits. The primary advantages are superficial: Ansys appears forward thinking to its clients, while IonQ gains a logo for its website and a press release to tout. IonQ's recent collaborations with the UAE and Busan Metropolitan Government follow the same pattern – long on hype, short on substance.

Last month's announcement of a $1 billion "Capital of Quantum" initiative with the State of Maryland and University of Maryland is another bit of clever marketing. Nowhere in IonQ's press release does it state what the actual budgeted amount is for this new public-private partnership, nor the fact Maryland is facing a nearly $3bn budget deficit, or that the initiative relies on a patchwork of state funds, matching federal grants, private sector investments, and philanthropic contributions *over the next five years*. The actual amount allocated to the initiative in Maryland's *proposed* budget is just $27.5m, with $10m earmarked for the expansion of IonQ's corporate headquarters – contingent on the hiring of at least an additional 250 employees.

Misleading Comparisons

> *“**If they did put Quantinuum in there, they [IonQ] would look pretty crappy.** There’s all sorts of ways to manipulate data to make yourself look good and that’s what’s going on here.”*
>
> — Former IonQ executive

According to multiple experts we interviewed, IonQ’s use of algorithmic qubits to compare its performance against superconducting qubits-based companies like IBM and Rigetti (p.15) is grossly misleading and outdated. As Quantinuum's critique of the algorithmic qubit metric highlights, IonQ employs the benchmark in a way that approximates logical qubit performance, but, in reality, it relies on a cherry-picked combination of simplified quantum simulations and a voting system to discard bad results. IonQ then juxtaposes these heavily post-processed results against the raw, error-prone outputs from IBM and Rigetti machines, creating a distorted comparison.

Notably, IonQ’s comparisons no longer include results from its closest competitor, Quantinuum – a company it once benchmarked against (p.13) – and continue to exclude results from neutral atom based systems, a modality which has made significant strides in recent years. This exclusion is particularly telling given Google’s recent strategic investment in QuEra, a leader in neutral atom quantum computing. Experts we consulted emphasized that IonQ’s selective representation of competitors might have been relevant four years ago, but the company has since failed to maintain its position in an increasingly crowded and competitive field.

IonQ is Not the Leading Trapped-Ion Computing Company

In our view, the dearth of publicly traded pure-play quantum computing companies distorts the view of the competitive landscape for investors. Quantum computing is a broad, highly competitive field with players on a global basis pursuing vastly different development approaches. Competition ranges from dozens of VC-backed startups to mega-caps like Google and Microsoft. US-listed publicly traded companies represent a small subset of the overall industry and neither IonQ nor Rigetti (NYSE: RGTI) were described by the experts we consulted as leaders in their respective modalities, let alone the industry broadly. Within the trapped-ion modality, privately-held Quantinuum was regarded as more advanced in terms of implementing quantum error correction, fidelity, and logical qubit demonstrations. IonQ has been more aggressively focused on scaling and modularity, but as just covered in this report, its reliance on photonic interconnects poses unresolved scaling challenges.

Conclusion

Much like quantum physics itself, the quantum computing industry exists in a state of superposition – where hype and reality overlap, promising revolutionary breakthroughs while grappling with fundamental engineering challenges. Companies promote ambitious roadmaps, employ misleading marketing tactics, change benchmarks on a whim, and frame trivial partnerships as groundbreaking achievements while CEOs offload millions in stock. But rather than accelerating genuine progress, this behavior blurs the line between real innovation and quantum exaggeration in an industry that many investors already find complex and esoteric. For IonQ, the real uncertainty lies in whether its history of bold claims will ever translate into a commercially viable system. With photonic interconnects still years away from enabling true scalability, we think the company’s history of lofty promises will remain just that – promises – rendering a crowded retail bet at current prices a fundamentally flawed gamble.

Appendix I: Quantum Computing Basics

Quantum mechanics is notoriously tricky to explain in simple terms, and many popular descriptions of quantum computing (particularly in wall street research and the financial press) take shortcuts that lead to misunderstandings. One of the biggest misconceptions is that quantum bits, or qubits, can be “both 0 and 1 at the same time.” From this, people imagine a quantum computer trying all possible solutions at once, instantly solving problems like the traveling salesperson problem. But that is not quite how it works.

More accurately, a qubit exists in a superposition of 0 and 1, meaning it has a certain probability of being measured as either state. Each state has an associated number, called an amplitude, which determines the probability of that outcome appearing. These can interfere with each other, like waves in water. Some cancel out (destructive interference), while others reinforce (constructive interference). The goal of a quantum algorithm is to arrange these interferences so that wrong answers cancel out and the right one is amplified, increasing the chance of measuring it. The challenge is to do this without first knowing the answer and arriving at it faster than a regular computer could.

This principle is why Shor’s algorithm was such a breakthrough – it showed how quantum interference could be used to factor large numbers efficiently, which is crucial for breaking RSA encryption. Other problems have been tackled using similar approaches, but only when they have the right mathematical structure. Quantum computing is not about blindly trying all answers at once; it is about carefully shaping interference patterns to extract useful results.

Another important concept in quantum computing is qubits can be entangled, meaning the state of one qubit is directly correlated with another, regardless of distance. In classical computing, bits operate in isolation from one another – the first 0 does not impact whether the next one will be a 0 or a 1. Qubits on the other hand, interact with every other qubit on a quantum chip, allowing qubits to work as a combined system. Every time a qubit is added to a system, the number of potential entanglements doubles and its computational power grows exponentially. Entanglement enables efficient information transfer and parallel problem solving, making quantum algorithms like Peter Shor’s for factoring large numbers and Grover’s for unstructured search exponentially faster than their classical counterparts – provided you have a sufficiently large, fault-tolerant computer of course.

A common misconception is that quantum computers are just faster versions of regular computers, like upgrading from a calculator to a supercomputer. The real advantage of quantum computing is in its “scaling behavior” – when the number of steps needed to solve a problem grows as the problem gets larger. Some problems that take an exponentially growing number of steps on a classical computer might only take a polynomial number of steps on a quantum one. For small problems, classical computers would still be faster and cheaper, but as the problem size grows, quantum computers could eventually outperform them.

But there is a catch: proving that classical computers cannot match a quantum computer’s performance is extremely difficult. Many times, quantum evangelists caught up in prevailing hype have thought quantum computing had an advantage, only for new classical algorithms to close the gap.

Appendix II: Ion Trap Overview

Trapped-ion quantum computers work by using electromagnetic fields to hold charged atoms (ions) in place, where they can be precisely controlled with lasers. This method has been used for decades in atomic clocks and is considered one of the most promising approaches for building useful quantum computers.

The process starts with lasers stripping electrons from neutral atoms, turning them into charged ions that can be held in place by an ion trap inside an ultra-high vacuum chamber. The vacuum is crucial because even a single stray molecule can disrupt calculations. Once trapped, the ions are cooled to near absolute zero using laser techniques. Unlike superconducting quantum computers, which require complex cryogenic refrigeration, trapped-ions can be cooled with just laser beams, making the setup simpler in some ways.

Quantum calculations are enabled by encoding information into the qubits and manipulating them using precise laser pulses. Each ion has its own focused laser beam, plus a global beam affecting the entire chain. By carefully timing and targeting these laser pulses, qubits can be switched between states and entangled with one another. Entanglement is achieved by making the ions vibrate in a way that links their quantum states together. Once the computation is complete, a final laser pulse is used to measure the results. The ions either glow (representing a "1") or stay dark ("0"), forming the final output.

For all of this to work, the qubits must remain perfectly isolated. That is why trapped-ion systems are placed in an ultra-high vacuum where there are nearly no stray molecules to interfere with them. While this approach provides highly stable qubits and precise operations, scaling up the technology remains difficult. Increasing the number of ions in a single trap while maintaining control becomes complex and IonQ’s path to scaling beyond ~200 qubits involves linking multiple traps together using photonic interconnects – a challenge that is still being solved.

Appendix III: Comparison of Leading Modalities

Quantum computing systems fall into two camps: natural quantum bits built around naturally occurring substrates exhibiting quantum properties or solid-state engineered qubits. Common natural quantum bit-based systems involve ionized atoms, neutral atoms, and photons. Solid-state based systems such as superconducting circuits use superconducting material which feature quantum phenomena at cryogenic temperatures. Spin qubits and topological qubits round out the group (not included below) and hold long-term promise but are less developed in terms of experimental demonstrations and practical scalability.

Quantum Computing Modalities – Key Metrics

	Superconducting	Trapped-Ion	Neutral Atoms	Photonics
	Google, IBM, Rigetti, IQM	**Quantinuum, IonQ, Oxford Ionics**	**QuEra, Atom Computing**	**PsiQuantum, Xanadu**
Qubit Count	100s to ~1,000, multi-die	~35-56	~200s	~12
Fidelity (2-qubit)	~99%-99.9%	~99.99%	99.5%+	99%+
Coherence time	Microseconds to milliseconds	Seconds to minutes	Milliseconds	Extremely short
Gate speed	Fastest (50-100 ns)	Slow (300-500 us)	Slow (300-500 us)	N/A
Operating temperature	Cryogenic (~10mK)	Room temp, but vacuum needed	Room temp	Room temp
Error correction overhead	High	Lower due to high fidelities	Moderate, still developing	Very high
Scalability	Cryogenic and fab complexity / industrial semi benefits	Photonic interconnects for 200+ qubit scaling	Error rates, atom placement, contol electronics	Photon loss, error correction overhead

Source: Kerrisdale research, Rigetti January 2025 Investor Presentation, McKinsey Digital, QuEra Computing April 17, 2024 press release, Xanadu Quantum Technologies Inc. January 22, 2025 press release.

Superconducting qubits, pioneered by companies like IBM and Google, is the most mature quantum computing approach and benefits from fast gate speeds, strong progress in error correction (Google's Willow chip), and can leverage mainstream semiconductor fabrication techniques, potentially aiding scalability. But because the qubits are artificially engineered rather than created from a naturally occurring atomic system like other modalities, superconducting currently suffers from manufacturing inconsistencies, leading to shorter coherence times and lower fidelity. The need for cryogenic temperatures also makes large-scale connectivity a considerable engineering challenge.

Systems that employ identical, "perfect," naturally occurring qubits have inherently stable and longer coherence, greater fidelity, and room temperature operational conditions. The drawbacks are orders of magnitude slower computational speeds and less established scalable manufacturing paths. Trapped-ion qubits, used by IonQ and others, offer industry leading fidelity and all-to-all qubit connectivity within a trap, but they have slow gate speeds and scaling issues arising from the complexity of controlling large numbers of ions. Neutral atoms, championed by companies like QuEra and Atom Computing, can be densely packed in scalable optical lattices, operate at room temperature, and, critically, show promising potential in terms of scalability. According to several experts we spoke with, while not as mature as semiconducting and ion traps, significant progress in neutral atoms in recent years has vaulted them to leading contenders in the race to develop large-scale, fault-tolerant quantum computers, as evidenced by Google's recent strategic investment in QuEra.

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