The Quantum Leap
May 31, 2022

A Review of ColdQuanta

A prior post entitled "Collaboration Dominates Quantum Computing" included an overview of ColdQuanta, a global quantum technology company building quantum computers, sensors, and related products. This post provides additional information and details on its broad yet complementary business units. As ColdQuanta management relayed to me, ColdQuanta is "not just a Quantum Computing company," it really is "a quantum technology company." ColdQuanta's strong history and momentum in quantum sensing, combined with its recently proven Quantum Computing capabilities, amounts to a powerful leader in broad quantum commercialization. This quantum platform focus supports an overall assessment of the likelihood of their success with a **Rating Alpha = 0.95/Exceptional Performance Expected** (see the Rating section for details).

Background

Based in Boulder, Colorado, ColdQuanta traces its roots to Drs. Eric Cornell and Carl Weiman who created the first ever Bose-Einstein Condensate (BEC) at UC Boulder in 1995, a feat for which they were awarded a 2001 Nobel Prize. BEC is a new form of matter, which is created when atoms are cooled close to absolute zero. ColdQuanta uses lasers to arrange either cesium atoms (cooled to a few microKelvin, or millionths of a degree for qubits) or rubidium atoms (cooled to nanoKelvin or billionths of a degree to make BEC, where the atoms act as a single quantum object and are used most notably in sensing) and hold them in place. Since temperature is a measure of kinetic movement, locking these atoms in place reduces their movement and hence, reduces their temperature. ColdQuanta uses this cold atom method across multiple quantum applications including gate-based quantum computers as well as a variety of quantum sensing and signal processing applications such as High Precision Clocks, Quantum Positioning Systems (QPS), Quantum Radio Frequency Receivers (QRF) and Quantum Networking and Communications. While Quantum Computing steals most of the "quantum" headlines these days, these other quantum-enabled devices bring enormous advances in their fields and, importantly, current revenues.

Core Technology

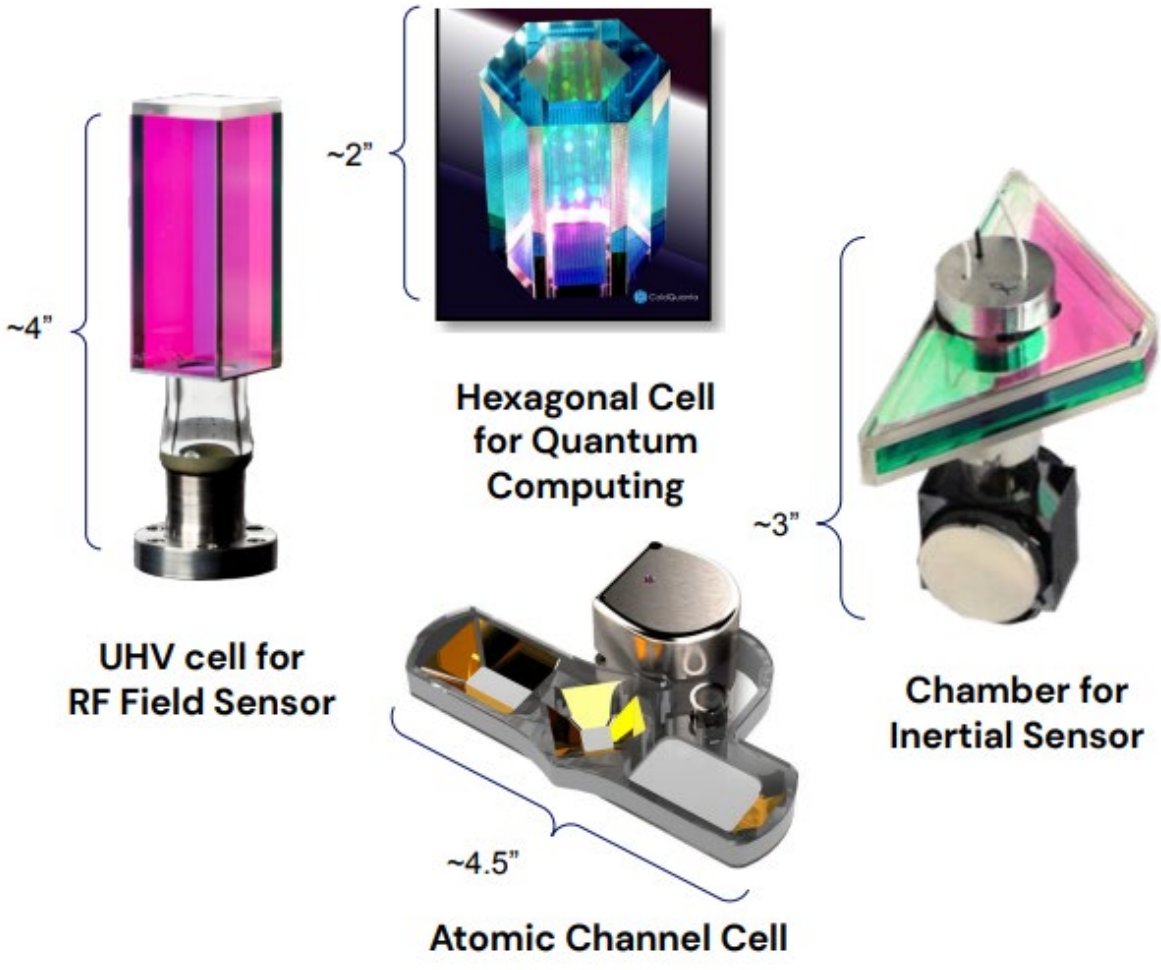
ColdQuanta, as its name implies, uses the quantum mechanics of "cold" atoms as its fundamental technology for a variety of important and compelling applications. As Paul Lipman, President of Quantum Information Platforms for ColdQuanta conveyed to me:

> "Atoms are nature's perfect qubit. Atoms are in and of themselves quantum objects. And by cooling the atoms down we remove noise and we're able to utilize their quantum nature for a variety of applications. So, it's one core technology, but with applications to

compute, to quantum signal processing, to quantum sensing, to extremely sensitive quantum clocks. We're addressing a wide array of applications and use cases and technologies but with a single core underlying 'qubit' if you will."

Here is a brief summation of how they can create so many disparate devices from a single, core technology [Hemsoth, 2021]:

1. Each device/application begins with a basic glass cell (see examples pictured below)
2. The cell is evacuated with an ultra-high vacuum (UHV)
3. They are then filled with atoms of a single element
4. Lasers are used to "trap" the individual atoms, which makes them cold, which in turn allows them to take on quantum properties
5. Other lasers then arrange the atoms in specific configurations, depending on the application. For example, a checkerboard-type arrangement is used to create qubits, counter-rotating atoms create gyroscopes and linear configurations can be used for accelerometers, etc.
6. For quantum computing, further lasers are used to further manipulate the atoms for computational purposes.



ColdQuanta uses this general configuration for two classes of products. One, manifested in its "Albert" quantum matter design platform, is used for quantum sensing and related applications and the other, referred to as "Hilbert" is used for quantum computing.

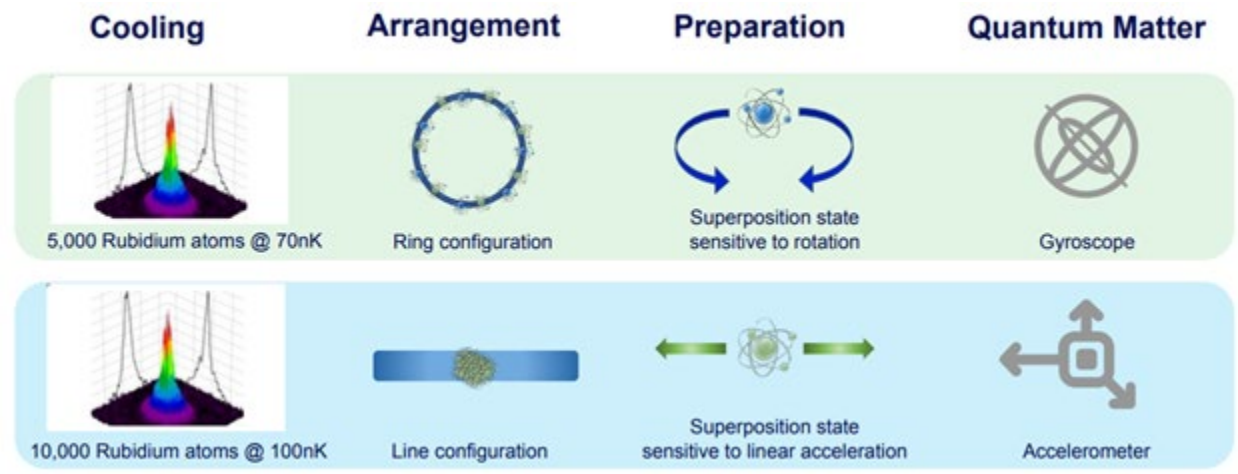
Albert/Sensing Devices

ColdQuanta has been selling its various quantum sensing devices and components for many years, to notable customers like the Office of the Under Secretary of Defense for Research & Engineering (OUSD R&E) which awarded ColdQuanta a $1.8 million contract, the Defense Advanced Research Projects Agency (DARPA) which awarded a $3.6 million contract and a variety of UK government initiative awards totaling $3.5 million.

In addition to selling quantum sensing products and components, ColdQuanta offers its "Albert" quantum matter design platform via cloud access. Users of the beta platform can now remotely create and manipulate Bose-Einstein Condensate (BEC) on a quantum platform enabling them to control and arrange the quantum state of Albert to define its dynamic behavior and then capture and evaluate the results to accelerate research and refine designs.

"Albert" is the showcase quantum matter design platform ColdQuanta offers, encompassing its capabilities around quantum sensing. The key to ColdQuanta's ability to leverage its cold atom system for quantum sensing is rooted in two important properties, among others. The first is the ability to place the individual atoms in a superposition (a fundamental quantum mechanical feature) and then measure the atoms to track ultra-minute changes and therefore "sense" various factors (i.e., time) with exquisite precision. The other is when adding energy to the atoms and placing them into a Rydberg excitation, which in turn significantly increases the "size" of the configuration (the insertion of energy expands the outer orbit of the electrons thereby stretching or enlarging the overall size of the atoms) creating a tunable dipole. This configuration is then extremely sensitive to radio frequency (RF) changes.

Examples of how users could create applications with Albert include the following:



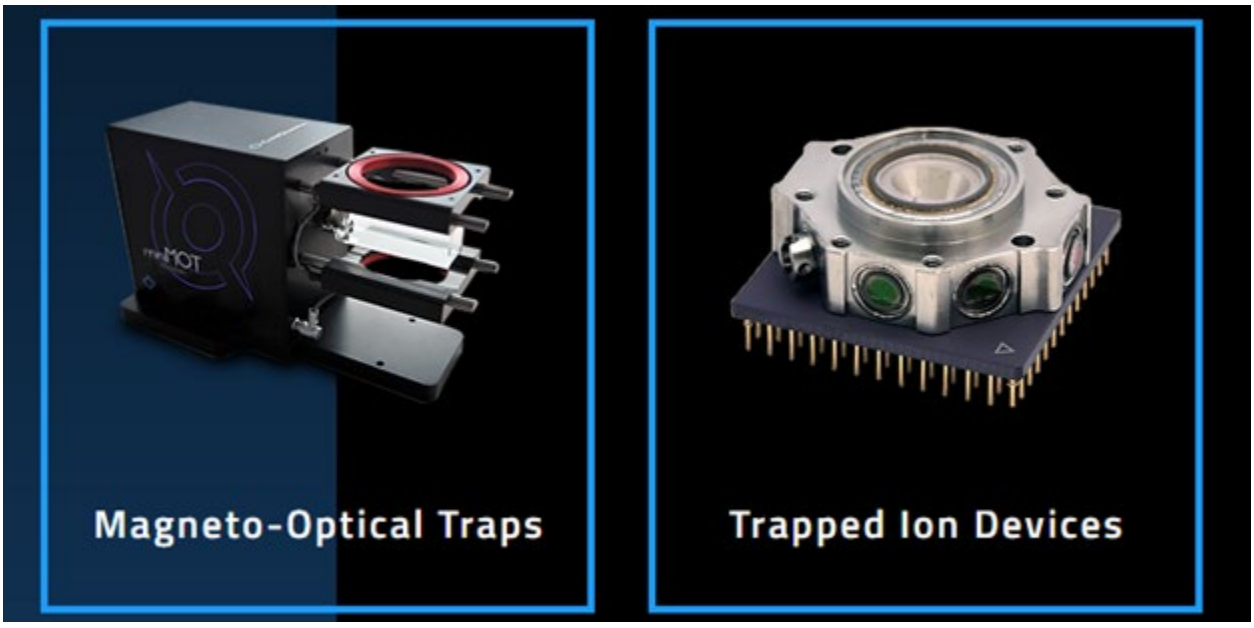
Quantum sensing underpins a number of important products including:

- Atomic Clocks
- Sensors
- Gyroscopes
- Accelerometers
- Gravimeters

These devices, in turn, enable or improved important applications such as:

- GPS Resilience
- Aircraft
- Power Grids
- Cell Towers
- Financial Trading Sytems
- Autonomous Vehicles
- Navigation Systems

ColdQuanta's cold atom approach enables the creation of ruggedized, portable and compact systems. In fact, they have successfully operated two different ColdQuanta systems on the International Space Station (ISS). In addition to the UHV cells shown on the prior page, ColdQuanta has a broad quantum product offering including the following:



In fact, since its founding in 2007, ColdQuanta has been awarded over $60 million in contracts. Selling these components to other pioneers in the evolving quantum space, should provide meaningful and growing revenues, akin to the selling of "picks and shovels" to the early gold prospectors.

Hilbert

ColdQuanta recently released its cloud-based quantum computer called Hilbert which will reach 100 qubits. Hilbert promises superior error correction, high qubit connectivity (starting at 4:1 but should quickly scale to 8:1 and ultimately closer to 100:1), long coherence times, and high gate fidelity, among other features. In addition, because neutral atoms do not have an electrical charge, they can be packed close together making this method of qubit construction highly scalable and compact. And most importantly, despite the super-cold atoms, the device itself operates at room temperature.

As Paul Lipman noted in a recent press release on Hilbert, "the commercial release of Hilbert marks an important and exciting milestone for ColdQuanta and for the cold atom quantum computing modality. Building on our recent world first in executing algorithms on a cold atom quantum computer, Hilbert demonstrates the power and scalability of atomic qubits and their promise to transform the quantum computing landscape."

Hilbert supports the Qiskit API and will initially be available in beta to customers through ColdQuanta's comprehensive multi-tenant cloud platform and soon via the Strangeworks Backstage Pass program (see below for additional details). Integration with public cloud services is expected later this year. The product roadmap calls for Hilbert to scale to 1,000 qubits by 2024 with the same strong connectivity, fidelity, and miniaturization at room temperature.

ColdQuanta Executive Management

ColdQuanta has over 150 employees including more than 90 physicists. They have cross-border facilities with a distinct footprint in Boulder, Colorado (USA), Louisville, Kentucky (USA) Madison, Wisconsin (USA), Oxford (England), and now Chicago, Illinois (USA). Senior management has deep and extensive experience in relevant quantum and technologically adjacent fields, and includes the following:

Scott Faris, CEO: Mr. Faris is an experienced technology company executive with over three decades of operating, venture-financing, and scaling experience including a diverse track record in new venture investment, technology company start-up and scaling operations, innovation process management, technology commercialization, corporate development and strategy, strategic alliances, and federal and commercial business development. This background seems well matched with the stage and general capabilities of the Company.

Paul Lipman, President, Quantum Information Platforms: Mr. Lipman is an experienced leader in emerging technologies. Lipman is currently a Board Member at the Quantum Strategy Institute (QSI). Most recently, Lipman was CEO of BullGuard, a global leader in AI-driven cybersecurity, which was acquired by Avira/NortonLifeLock. His career experience includes the development of the world's first IoT cybersecurity solution, Dojo (acquired by Forescout Technologies) as well as leading multiple innovative cybersecurity companies to successful exits. Prior to BullGuard, Lipman was CEO at SASE pioneer iSheriff (acquired by Mimecast). Earlier in his career, he held CEO, GM and executive leadership positions at Webroot, Keynote Systems, Total Defense and Accenture. Based in Silicon Valley, Lipman holds an MBA from Stanford and a bachelor's degree in Physics from Manchester University in the UK.

Chester Kennedy, President, Research & Security Solutions: Mr. Kennedy has had a career focused on innovative technologies and their impacts on a variety of industries. Kennedy served as the Chief Executive Officer of BRIDG from 2015 to 2020, leveraging his aerospace and commercial electronics industries experience to lead the construction of a microelectronics fabrication facility and the establishment of a robust customer base. Before BRIDG Kennedy spent 30 years at Lockheed Martin and its heritage organizations most recently as Vice President and Chief Engineer of Training and Logistics Solutions at Lockheed Martin Mission Systems and Training.

Dana Anderson, Co-Founder and CTO: Dr. Anderson is co-founder and former CEO of ColdQuanta. He is a Fellow of JILA, and a Professor in the Dept. Of Physics and Electrical & Computer Engineering at the University of Colorado. He is also Director of the Quantum Applied Science and Engineering (QASE) at CU Boulder. Since 1993 he has been involved in guiding and manipulating cold and ultracold atoms. He and his collaborators Professor Carl Wieman and Dr. Eric Cornell (2001 Nobel Laureates in Physics) first demonstrated guiding of cold atoms through hollow core optical fibers in the mid-1990's. Drs. Anderson and Cornell performed many of the earliest works guiding cold atoms on an "atom chip," including the first demonstration of a chip-based atom Michelson interferometer. Professor Anderson's group demonstrated the first ultracold atom chip portable vacuum system in 2004 and has been heavily

involved in DoD-funded activities to develop ultracold atom chip. Dana received his Ph.D. from the University of Arizona and undergrad from Cornell.

Mark Saffman, Chief Scientist for Quantum Information: Dr. Mark Saffman, Professor of Physics at the University of Wisconsin-Madison is a preeminent expert in neutral atom quantum computing. He is an experimental physicist working in the areas of atomic physics, quantum and nonlinear optics, and quantum information processing. In 2010 his research team was the first to demonstrate a quantum CNOT gate and entanglement between two trapped neutral atom qubits. Mark has been recognized with an Alfred P. Sloan fellowship, the Vilas Associate Award from the University of Wisconsin-Madison and is a fellow of the American Physical Society and the Optical Society of America. Mark worked as a Technical Staff Member at TRW Defense and Space Systems and subsequently as an Optical Engineer at Dantec Electronics Inc. in Denmark before going back to graduate school to earn his Ph.D. in Physics from the University of Colorado at Boulder. Mark received his B.Sc. with honors in Applied Physics from the California Institute of Technology.

Competition

While there are a number of competitors in the quantum sensing space, most are early stage, less well capitalized or have a narrow product focus. Certainly, some of these companies, such as Qnami (imaging and diagnostics), Innatera Nanosystems (medical sensors), Spiden (medical sensors) and QDTI (medical sensors), may develop strengths in a narrower field within quantum sensing, but none have the breadth of offering that ColdQuanta offers. Within Quantum Computing specifically, there are a few neutral atom competitors including Atom Computing, Pasqal and QuEra. Each of these QC competitors is also working towards using netural atoms as qubits, with Atom releasing its 100 qubit Phoenix system in July 2021, Pasqal's 100 qubit machine coming soon to the Microsoft Azure platform, and QuEra's planned for release on Amazon Braket later this year. Since all these neutral atom quantum computers are extremely early in their release (or imminent), it is difficult to assess the feature and benefit differences among them. Additionally, other forms of qubit, are already powering various quantum computers made by IBM, Rigetti, IonQ, Quantinuum, and others. Each of these other qubit modalities have various strengths and weaknesses compared to the ColdQuanta structure so it will be interesting to follow the industry and see which platforms garner the strongest following and commercialization momentum. That said, in this early stage of QC, there are broad opportunities for early movers, including ColdQuanta, to gain traction and ultimately customers.

Funding

ColdQuanta has completed a series of investment rounds totaling $68.75 million so it has been well capitalized. Their original funding in 2017 came via a $12 million grant from Small Business Innovation Research. This was followed by a $6.75 million seed round in 2018, led by Maverick Ventures and joined by Global Frontier Investments (each receiving board seats). Several additional grants and seed investments were received in 2019 and 2020 and a $32 million Series A round was completed in late 2020, with existing investors participating and joined by Foundry Group and Lennox Capital Partners. In 2021 a later stage venture round of $20 million was completed with GrayArch Partners and Wisconsin Alumni Research Foundation

joining with the existing investors. Overall, this represents a well-capitalized enterprise supported by some prominent names in venture investing.

Collaborations, Partnerships and a Recent Acquisition

In the prior post on Collaboration Dominating Quantum Computing, some of ColdQuanta's various partnerships and collaborations were highlighted, so readers of that post may recognize some of the following details:

Super.tech

In May of this year, ColdQuanta announced the acquisition of software startup Super.tech, known for its innovations in quantum software. Super.tech, co-founded by Pranav Gokhale and Fred Chong, is a member of the first cohort of the Duality incubator, run by the Chicago Quantum Exchange and the University of Chicago. Super.tech has developed SuperstaQ which enables users to write quantum programs in any source language and target any quantum computer, providing API endpoints that enable deployment of quantum solvers for practical applications, without needing any quantum experience. It has also created the SupermarQ suite of quantum computing benchmarks. Super.tech will become the Chicago office of ColdQuanta and Gokhale, Chong and the other dozen or so Super.tech employees will join the ColdQuanta staff.

Classiq/ColdQuanta

In January of this year ColdQuanta and Classiq announced a partnership to make 100-qubit quantum circuits a reality for companies and researchers seeking quantum computing solutions. The partnership combines ColdQuanta's cold atom quantum computers and Classiq's quantum algorithm design software. They aim to provide customers with the ability to create, simulate and execute unique quantum circuits to address a wide range of finance, material science, supply chain, and machine learning challenges. As Nir Minerbi, CEO of Classiq noted, "as the industry moves from toy problems solved by toy circuits running on small quantum computers to solving real problems that require complex circuits on larger quantum computers, there is an acute need for a high-level platform to develop these circuits quickly and efficiently." By entering into this partnership now, the companies should be well aligned to scale together as ColdQuanta releases larger QCs in the future.

ColdQuanta/Strangeworks

This past December, ColdQuanta and Strangeworks announced the addition of the forthcoming Hilbert Quantum Computer to the Strangeworks Ecosystem. Hilbert will be available for early access by select members of the Strangeworks Backstage Pass program with general available later this year. As noted above, the Backstage Pass program is a vital tool for early development and evaluation of new QC capabilities, and ColdQuanta is benefiting from important feedback in advance of its broader public release. Think of it as a beta release which is accessible to an optimal set of users and therefore able to provide deep insights on strengths and weaknesses of the system.

ColdQuanta/IBM Q

In May of last year, ColdQuanta announced that it had joined the IBM Quantum Network and would be integrating IBM's Qiskit open-source software development kit (SDK). ColdQuanta plans to make its Hilbert QC available via IBM Q, IBM's quantum network, and combined with its integration with Qiskit, will enable ColdQuanta customers to accelerate their quantum computing initiatives. The companies also noted that they will pursue joint development opportunities with the goal of accelerating the adoption of other quantum technologies.

Learning More

For quantum enthusiasts and investors seeking to learn more about ColdQuanta and their Albert and Hilbert platforms, I encourage you to visit their website and sign-up for updates. They are also highly active in the various quantum conferences held throughout the year, so you can learn more by speaking with them at any of those in-person and/or on-line events. They are also quite active on the social platforms including LinkedIn, Twitter, Facebook and YouTube and I encourage you to follow them on any or all those mediums.

For prospective customers interested in their sensing devices, it's easy to create an Albert Beta Account here, or review some of their Albert resources and documentation here. For more information about their various sensing products, they maintain product details here. For details about their Hilbert universal and scalable Quantum Computing platform, visit here.

Summary

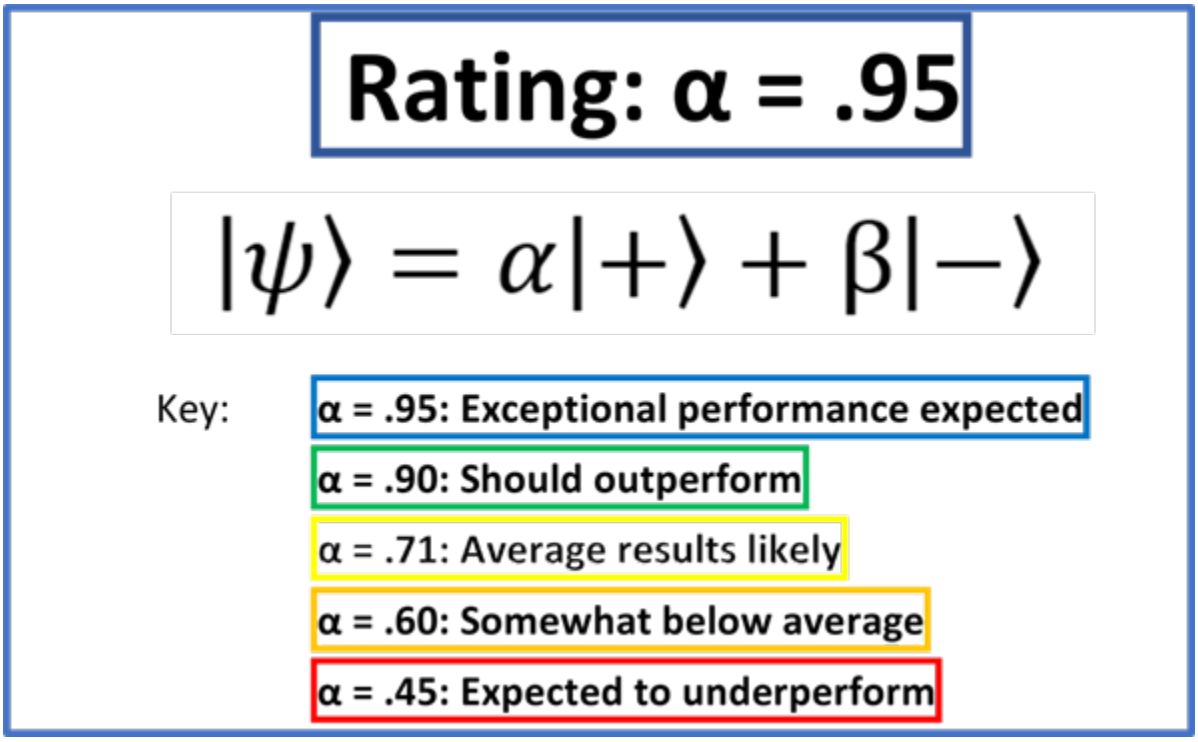
ColdQuanta has a solid team, protective IP, a highly regarded product portfolio, a strong balance sheet, and now a quantum computing platform. It has diverse customers, legacy revenues, and should enjoy synergies both between its two broad "quantum" offerings (sensing and computing which both leverage neutral atom configurations) and now across its Quantum Computing hardware platform and recently acquired software platform. A later start to Quantum Computing, and a broad geographic footprint provide a few modest headwinds. The following table highlights some of the key attributes of ColdQuanta:

Strengths:	Opportunities:
• Real customers and meaningful revenues. • Its core cold-atom method can be leveraged across may applications. • The business is well capitalized having raised over $68 million from a strong and broad group of venture investors. • Strong intellectual property portfolio with nearly 50 patents.	• Ability to leverage its early quantum sensor lead in added products and now, for quantum computing. • Selling quantum "picks and shovels" to others is a rapidly growing business. • With over 90 PhD physicists and engineers, one of the largest talent pools in the industry, the business is well positioned for future growth/products.
Weaknesses:	**Threats:**
• New to quantum computing with Hilbert only very recently released, operating in a highly competitive space. • Somewhat geographically scattered executive team may drag on corporate culture.	• Others, some with significantly more capital, are competing head-to-head with ColdQuanta, including others with similar neutral atom formats. • Their cold atom methodology is still early in quantum computing, others using superconducting or trapped ions have a meaningful head-start in QC.

Rating

Apropos of the probabilistic nature of quantum algorithms, I wanted to leverage the nomenclature to create a company rating system and assign a scale to my overall assessment of a company's potential. Accordingly, I am going to use the formula below when reviewing companies, whereby the "alpha" coefficient correlates with "positivity" (and the formula adheres to the Born rule).

Given my overall assessment of ColdQuanta including its strong IP, broad and complementary offering, and prestigious existing customers (and revenues), I am assigning the highest rating to ColdQuanta at this time, with an **Alpha of 0.95** which equates to an "Exceptional performance expected." When I began researching the Company, I had originally considered an evaluation one notch lower due to the non-availability at that time of their Hilbert Quantum Computer, but the release of the device provided the added impetus, in my view, to award this highest rating.



***Disclosure**: The author has no beneficial positions in stocks discussed in this review, nor does he have any business relationship with any company mentioned in this post. The views expressed herein are solely the views of the author and are not necessarily the views of Corporate Fuel Partners or any of its affiliates. Views are not intended to provide, and should not be relied upon for, investment advice.*

References:

Lipman, Paul. Interviewed by Russ Fein, April 27, 2022 and March 11, 2022.

Graham, T.M., Song, Y., Scott, J., et al, "Multi-qubit entanglement and algorithms on a neutral-atom quantum computer," *Nature*, April 21, 2022.

"Collaboration Between Leading Quantum Organizatoins Achieves Industry First for Neutral Atom Quantum Computing," *PRNewswire*, April 20, 2022.

Hemsoth, Nicole, "One Company Could Own the Quantum Product Spectrum," NextPlatform.com, February 1, 2021.

If you enjoyed this post, please visit my website and enter your email to receive future posts and updates:
http://quantumleap.blog

Russ Fein is a venture investor with deep interests in Quantum Computing (QC). For more of his thoughts about QC please visit the link to the left. For more information about his firm, please visit Corporate Fuel. Russ can be reached at russ@quantumleap.blog.