FUTURE SIGHT PODCAST

Ep. 36: The Quantum Effect

Future Sight Podcast by Capgemini Invent

As business and technology move forward at a rapid rate, it has become increasingly important to explore new ways to adapt and grow for the future. This podcast is your guide to that future journey.

Join us as we explore a new topic in business, technology, and transformation. Find out more about the challenges businesses are facing today and what they can expect in the future. Listen to leading industry experts as they break down need-to-know, actionable approaches with strategic insights and provide tangible takeaways.

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Episode Transcript

Ollie Judge: This is Future Sight – a show from Capgemini Invent. I'm Ollie Judge. On this show, we explore new ways for you to adapt and grow for the future in business.

Quantum technologies have been on the horizon for a long time now. And with upwards of 20 years in development, investment and research, quantum technology is now.

Here at Future Sight, we've gathered some of the world's best quantum experts to give you the information you need to know about quantum tech, and how it's going to affect the future in business. Joining me today to explore this are experts from Capgemini -

Julian van Velzen: Hi, I'm Julian van Velzen. I am the head of Capgemini Quantum Lab. And I'm part of the group CTIO community.

Ollie: …And from IBM.

Olivia Lanes: Hi, my name is Olivia Lanes. I am the lead for North America at IBM quantum for Qiskit Education and Research.

Ollie: …And from Atom Computing.

Rob Hays: Hi, I'm Rob Hays, CEO of Atom Computing.

Ollie: So from the beginning, for people that maybe don't know: what is quantum computing? And I'm not even going to go into the application yet.

Can we just talk about what the difference between normal computing and quantum computing might be? I'm going t0 – Rob looks confident here, so I'm going to kick to him.

Rob: Yeah, quantum computing is a kind of a new form of computing that instead of using ones and zeros and having to iterate through problems using binary code, it uses these things called qubits, which are the fundamental building blocks of quantum computers. And qubits can hold a much larger range of information simultaneously between them to flip, to do computations, across a set of coefficients that are much more complex and can drive, I would say, higher kind of more parallel programming for higher performance – the way you could get out of a classical computer using bits.

Ollie: Cool. So if you were to explain that to someone like they were five, how would you say that? What's the kind of like difference there that if someone. Doesn't really know anything about computing, right? That like what, what are going to be the big differences going into the future?

Rob: I think I'd love to hear what Olivia has to say with that.

Olivia: I always have an analogy that I use when somebody asks me to explain quantum computing to a five-year-old. So my favorite analogy is it's like classical computing. So for classical computing, bits are like light switches, right? You can flip them off and you can flip them on not, you can't have any other state in between.

And for a quantum computer, we use quantum bits – qubits. So instead of a light switch, I want you to think of a sphere. Instead of having a vector or an arrow that points up or down, it can point to anywhere on the surface of the sphere, right? So there's an infinite number of states, which means you have a much, much larger computational space.

It's just a bigger area in which to perform computations. And in addition, if you were to have, a bunch of bits, a bunch of light switches, this only grows linearly. But if you have a bunch of spheres and you're somehow able to couple those together, that computational space will grow exponentially.

So you can think about just comparing, five bits to five qubits. You have so much more space in which to perform computations. So that's how I would explain quantum computing.

Ollie: All right. And then my next question is going to be, how do we actually use these new ways of doing things? What is quantum computing capable of that we haven't seen before?

Julian: It's pretty difficult to explain how exactly quantum computers work. And we covered the basic, like what our qubits, but then to go from there to some algorithms and then to some applications, it's not straightforward

– it’s pretty complex. Whereas the way these computers work is pretty complex, it's purpose, I would say, is pretty straightforward, right?

It's just a massive amount of compute power for very specific applications and in a very specific way, a lot of compute power. So to your question, what can we use this for… well, the first area where we can really look for where we want to use them is in places where we want to have a lot of compute power.

So for example, in very large complex simulations in chemistry or physics, or maybe in finance or life sciences or material sciences. And that's also where I see a lot of innovation and a lot of people exploring what you can exactly do with these things.

Ollie: And Rob, what would you say? The primary application that you could see, maybe not on the near future, but one of the first things that could come under quantum computing is – when?

Rob: Yeah. I think if I think about like conversations I have with customers or partners, it seems like optimization problems around logistics and shipping seems to be one that's quite popular. And this is where you can use the advantages of the qubits that they can hold all these different states and explore different solutions that's simultaneously to your advantage and that you could take, think of a multipathing kind of mapping problem, where you've got lots of inputs and lots of outputs in different destinations and different potential paths that you could follow.

And how do you explore that kind of map space, in parallel, in a way that you can get a more optimal solution or set of solutions is one area that I hear a lot of companies and customers wanting to go explore.

And the benefits of that as you could get, packages or things, from point A to point B much faster and cheaper, less fuel, because you've got a more optimal path. And one of the reasons that's maybe more of an early use cases you can do that using what we call these NISCAIR machines, where maybe they're not fully error corrected or fault tolerant machines.

Because you're not necessarily looking for the correct answer, but you're looking for a better answer, a more optimal solution set than the one you would have using manual methods or other, classical computation methods. And so, it's okay if there's a little bit of noise, as long as you're getting a better answer, there's value being created.

So I think that would be one reason why that would be an early kind of use case that people are exploring.

Julian: Maybe if I can reply to that to make it a bit conversational and also not to completely agree with each other, I think that's always more fun. I think that optimization is definitely one of those cases where I can really easily imagine how classical computers completely blow up – calculating the routes between 10 cities. And then you can do it on paper and then thirties – it’s really impossible. And I think everyone can imagine how these problems are everywhere. And I think that's one of the reasons why it's very exciting because indeed, if you have a small benefits, then you could really make a big impact.

But I think because it's so easy to imagine and because it's so often present that it's maybe the go-to thing where people explore first – if the one that get into it, but not necessarily the best one. And other problems maybe if it was something very specific chemistry or maybe some very machinery type of problem that's not very common. Maybe a much better use case but just much harder to discover.

Ollie: So I want to talk a little bit about where we are in the timeline of quantum computing. For me, it's watching those videos of a computer hanging from the ceiling with a bunch of cables coming off. I'm sure we've come a bit further than that. But Olivia, could you give us a bit of background on what the maturity state of quantum is and how people should maybe be let's say mediating their expectations around like where it is right now?

Olivia: So I always describe quantum computing as an emerging technology. I think it's really important whenever we're talking about applications to emphasize that these are potential applications. And that the paradigm shift that we refer to as quantum advantage, which is the point at which quantum computers will be able to do something useful, has not been reached.

So this is a technology that we believe will have tremendous implications across all sorts of different fields. We've already mentioned a few here. But right now we're still working very much at the PhD, physics, engineering, chemistry, scientific research level.

Ollie: Nice. And does that mean in terms of talent in the space… and who's getting involved. So, we've got, we've got an educator, we've got researcher, we've got person from Capgemini ready to take on the world with what's next. Who can begin to look to quantum tech as a thing that they could maybe be involved in?

For example, if outside in, looking from my perspective, do you need to be like a scientist to understand this?

Olivia: So, I don't think you need to be like a PhD scientists to get involved in quantum computing. I think this is a myth we're trying to dispel. And in fact, there are so many new quantum jobs that have emerged recently that every single one of them can't be a PhD level scientists because we have too many open jobs.

So you can come in. I think with all sorts of different backgrounds. We work and we hire people who have backgrounds in computer science, information science, chemistry, biology, even from the bachelor's to people who have done multiple postdocs, all sorts of different levels.

And I think something that has been happening recently that I just want to mention, because it's super interesting to me anyway, is that just in the past few years, I've seen a bunch of programs pop up for people to get a degree in quantum information science or quantum engineering. Not just a PhD again, like bachelor's, minors, master's degrees, just in the past few years.

So any sort of different education level from any sort of different technology background can get involved.

Rob: I would just add, I totally agree with that. I would add and it may be counterintuitive that it's actually easier for a company like ours that's building quantum coding hardware to hire the physicists and the PhDs out of the physics labs at the universities because everybody wants to be involved in something big and quantum computing is big, and there's only so many companies that are developing the hardware.

Those are pretty desirable jobs and we're able to cherry pick the best and the brightest out of those postdoc programs and so forth. And so that's not really the hard part. It's essential but not as hard. The harder part is just getting software engineers and electrical engineers that can do FPGAs and circuit boards. And the more classical engineering and software development roles, because the competition there is so much stronger because you're competing against large cloud service providers, large multinational corporations. There's just so many more jobs out there and people. It's a little harder to get the more plentiful resources, which I think is counterintuitive.

But, it's also where we're hiring more people right now because you only need so many PhDs to go and design hardware and build some of the basic physical elements of the quantum computer. But you need a whole host of folks to go build them into systems that are reliable and offered through the cloud and APIs and security and all the other stuff you need to go build on top of them to make them useful. And there's more jobs available in these other disciplines that are more classical and it's actually harder to find the people.

Olivia: Yeah, Rob's totally right. And just piggyback off that, one thing I didn't even mention is, product managers, program managers, these people have all sorts of different backgrounds and training, and they're really important to the quantum workforce. But it can be hard to find people who have the sort of necessary insight into quantum technology in order to fill these roles.

Ollie: How does a company begin to even look in here? So if we've got IBM, Atom, Capgemini here, like everyone's got an initiative around this. But it's a high bar to just try and get the right people on board and start to talk about this productively.

So, what's the common thread there between all of you that has driven you towards this point where you're "yes we really need to get our arms around this and we really need to like find ways that this can be productive industry in the short term and the long-term?"

How does the company even start?

Julian: So I think that one thing that Olivia and Rob already mentioned was that the PhDs that we need for the hardware development, or maybe the most technical things, and maybe some of the R&D development, it's not that many people.

I had a conversation with Neil Abroug. He is the lead of the quantum ecosystem in France. And he mentioned that in 2030, he would expect something like 50,000 PhDs to be trained. And I think that number is pretty modest, right? It's a definitely a challenge to train so many people, but it's still relatively modest. I think we would need far more people in all these side things from the security aspects to the quantum algorithms for finance, for the different other industries. And also your infrastructure to security, all kinds of things, that are you have to have both knowledge of quantum and have some domain knowledge.

So what we did was to set up a small team that's really of the core scales, core competencies, but really create a much wider group around that. So if people that are interested in and have some affinity with, is maybe you have a, maybe a background in physics or something technical that helps.

But also some other knowledge, maybe. Some experience, for example, in complicated multi-product simulations that are used to finance, or something else that they can bring to the table. We were really surprised if that's in a company as big as ours.

And I think that must be the same for Olivia as well. There already are thousands of people that are interested now, it's really a hot topic. Everyone wants to know about quantum. So it was quite a luxury to just nurture those people and get them to be excited about this and learn more about this.

And that can really be an excellent group of people that got started from – to engage and to learn from, and to get some ideas out of; build small teams. And then if all these people get together and there's some small team that facilitates it, I think that can be like a flying wheel to build momentum on its own.

Rob: For our organization, it's easy. Cause we only do one thing. We build quantum computers. So it's not an initiative, it's who we are. But I think the question is how do others like partners or customers who maybe have other tasks that they do with classical computing or maybe their whole business is built on cloud services or something – how do they incorporate quantum computing into what they're doing whether that's research or part of their business in the future?

And I think it starts with learning, engaging with people like Olivia, and Kiska program is a great way to learn. Engaging with hardware vendors like IBM or Atom computing to test out some algorithms and start to understand the behaviors and the responses. And just, how do you interact with these machines?

It is a good way to get started. And eventually, when these systems get bigger and more kind of production scale, which they're not really at now for large commercial value kind of applications, then I think there's going to be a whole bunch of different experts out there like Capgemini and other consultants who are able to help big companies understand how to use these machines and programs and what applications might be useful and how to integrate them in with their existing compute workflows in a hybrid compute model.

So I think it's going to be a journey. It's not gonna happen overnight. The companies that get started early are probably going to be the ones that find the competitive advantage and the ones that go late will be disrupted or will have to play.

Olivia: I totally agree. Everything that Rob said. I think companies that begin early will eventually have a competitive advantage. You don't need to have a huge team on board that are all quantum natives. I think it all just begins with a few people, and we're focused on education.

Julian: So I think both of those of you said is that no one can really do this whole thing alone. At least on some level, you need to find the right partners. Either that's finding the right hardware or that's finding the right, maybe even partnerships with academia or maybe just to get insights from, or maybe even to get talents.

Maybe some of your competitors, I think it's quite early for some use cases, relatively early still. So you can learn a lot from competitors. That's beautiful ecosystem of players. And I think it's really, it's just not something you can do on your own. So it makes sense to look who to partner with early.

Rob: Yeah, one thing, I'm sure I was just as hard. Partnering with folks who have know-how in different layers of the solution stack and applications, I think will be essential.

Ollie: So I want to capitalize on two of those comments there. This is hard. And also, I think there's a bit of an elephant in the room over hardware, which is, like we've actually got to build these things and not a lot of people build these things. I'm going to go over to Olivia on this one. What does the hardware look like?

How is it different from what we know today? Does it need special conditions to run, all that kind of stuff? Why aren't we using quantum compute right now? And. And can you tell me a little bit about that whole process of maybe this is a little bit harder than we would think of just offloading some stuff off and hoping for the best?

Olivia: Yep. So it's an entirely new hardware. It doesn't run with any existing hardware stack that you would use for classical computing. So we spoke about qubits a little bit already, but what we didn't talk about is that you can make qubits out of a bunch of different platforms.

You can make qubits out of atoms. You can make qubits out of super inductors, which is what IBM focuses on. We call these pseudo atoms. And then I think Rob can probably give some better insight into his own company's hardware platform. But there are a bunch of different hardware platforms that you can use to create a qubit. And they all have pros and cons. There's not like one perfect technology, right? They all sort of balance each other out.

And it's not clear if there's going to be like one winner in the end of this either. We could use different hardware platforms for different applications as well. So the hardware that IBM focuses on and that I did my research on for my PhD is with superconducting circuits.

And basically these are 2D, very tiny nano circuits that are laid out on different chips and processors. And again, everything is made out of a superconductor, which means that it has to be cooled down to impossibly low temperatures, like 10 millikelvin in order to achieve superconductivity and to get rid of any sort of environmental interference, because qubits are incredibly delicate devices that like to decohere.

And by decohere, they like to not keep track of their information and that's bad when you're trying to run algorithms, which rely upon knowing previous states of information. That was a long spiel, but superconductors is what IBM uses, what Atom uses. I'll pass it off to Rob. I'm sure he can talk more about his platform.

Rob: Yeah. And at the end of the day, we're all trying to build systems that kind of have the same behaviors around the same gate set, run the same algorithms, use the same software developer kit platforms like Qiskit and others. But the underlying kind of hardware is quite different. So unlike superconductors, we're not having to manufacture any chips.

We don't control them with RF tones over wires. We control RF tones that go to lasers and the lasers interact with the atoms that were trapping in a vacuum. So there's quite a bit of differences in the hardware underneath. And like Olivia said, there's pros and cons of each approach. Superconductors have been around a lot longer than the trapped atom-neutron technology that we're using as far as applying it to quantum computing.

So, there's been an opportunity to get gate fidelities up, which is just the inverse of get hurry and errors' down clean out the noise, get the systems to perform fairly well. We're playing catch up there because we're much newer. So we're having to do all the things that companies like IBM and Google and others had done prior in getting gate fidelities up.

But we have an advantage in coherence. Olivia brought that up. The coherence on the neutral atoms is tens of seconds for every qubit. So that's like a ridiculously long time. It's longer than you really need to do computation, which is good. It just means it's not really an issue.

And there's opportunity to scale using the neutral atom platform because of the wireless control. And this all happens in a very small kind of micron scale sort of space in a vacuum chamber. So the systems are relatively small, and we don't have to worry about wiring up millions of qubits together.

We control them with different spots of light. So that's the promise of the technology and, a little bit how it's different than a superconductor, but at the end of the day, the systems, like I said, are really going after the same solution space, as far as building gate based computers that perform well for end users.

Ollie: So I want to build on that side and twist that into application, right? So we're talking about different types of computation and like maybe faster, wider… One of my favorite examples, I'm not sure who came up with it, but around quantum computing is that it could pretty much unravel the whole cryptocurrency market overnight if it was actually applied correctly.

And that may be wrong though. So I'd like you to come and fight me on that one, but I'd like to understand, what the applications are here? And where do things go further than what we would expect from computers today? With quantum computing, from what we've already covered, new opportunities are being opened up.

<u>What are those opportunities?</u> How should people begin to think about how they would approach this technology? Not from a "how do I get into quantum," but more "how does this letters us do a long jump from where we were before?"

Julian: All right. So I heard a couple of different questions that you mentioned. So there was one about the security aspect. So let me start there. So there is an algorithm that has been pretty old: Shor's algorithm. I think 92, but I'm not exactly sure. And that is to break cryptography. And even though the computers aren't there yet, when the computers will be there, there will have a massive impact on our whole IT security landscape.

And even though computers will need to mature a lot more. I think it's really now the time to start preparing your IT landscape to prepare for that. For a couple of reasons. One reason is a lot of things has to be changed, all kinds of cryptographic standards, public key infrastructure, as well as age, all kinds of things that I use in cryptography has to be updated.

And the problem is you don't really know where it is, right? So you have to have a very careful analysis of your cryptography. And that's just very complicated, it would take a lot of time. Why should you start earlier? Why should you start now?

So I mean, the first use case where I, where you can look for is just where you have a lot of compute power for classical systems and where you hope to speed things up a little bit more. But I don't think that's the full promise of quantum technology, right? If we will be 20 years down the line, there will be all kinds of new business models and all kinds of extreme stuff that we will be able to do with these kinds of machines that are completely impossible.

They're really beyond what the current systems would be. Two, to get started today, it does make a lot of sense to find the smallest possible problem that you can find, something that you can really define very clearly mathematically and try to learn as much as possible from it. But in the long run in, in all kinds of industries, you think about life sciences. If you think about to simulate large number of molecules predict all kinds of chemical properties that you would just have to synthesize now in the lab. Being able to bring down the diamond takes for a drug to go through markets or fight or feel fast, quick, much faster. I think this is just some of the opportunities that could be.

Rob: I think one of the most fun things about this question is that the answer is we really don't know. When you're asking a far in the future kind of question as to what is it that's going to come about that we don't know about today? And the answer is we don't know! It seems obvious, but you just think back 20 years ago, like you probably wouldn't have ever seen some of the natural language translation processing and image search, and some of the cloud services that are out there and augmented reality and all this cool stuff, that's come along in the last, 5, 10, 15 years or whatever.

What have you want to do with quantum computers? So, we have some ideas. And it's important for us to search for those early use cases so that, we can start to get the flywheel going on the commercialization and all that. But the fun part is just, we don't know. There's going to be things people invent that probably blow our minds, today's minds and they'll just seem normal in the future.

And I think that's pretty amazing.

Olivia: Yeah, Rob stole my answer. I was going to say, whenever somebody asks me what my favorite application of quantum computing is, I always say, I hope it's something we haven't even thought of yet. Because I really do believe that it could impact every other technology field. So we talked already about, you know, optimization.

We haven't talked so much yet about simulations of nature. That's pretty cool. I think there's going to be some really interesting applications in terms of modeling chemistry, pharmaceuticals. I think we'll see some really cool stuff come out of that. But yeah, I totally agree. I think it's exploding. I think there's a lot of interest in it.

There's a lot of brilliant people in the field working on it. I think the best applications are things we're not even talking about yet.

Ollie: I think that makes sense, especially into looking into things like life sciences, where there's been giant leaps. We've gone from standard CPU compute there to GPU compute, which has helped open that whole world up. And I can only imagine that quantum is going to leap frog all of that into a completely different set of simulation styles, but also a different way of thinking about stuff.

I'm going to move on. And I want to know what you all think is the biggest road blocks for quantum coming into sort of a generalized use case. Obviously, there are hardware constraints. There are software constraints on maybe some of the interfaces aren't correct for every application quite yet. I would like from all three of your perspectives where you think the stoppers are currently, and the things that are potentially holding quantum back a little?

Rob: I guess if I had one wish for quantum, they would be just that we could fast-forward to like systems that are our millions of cubits, just really much larger than we are today. We're orders of magnitude behind where we really need to be. When you think about like fault tolerant computing and error corrected – there's this mapping from a large number of physical qubits to a much smaller number of logical qubits that are statistically guaranteed to be accurate and deliver accurate results.

And with systems that are like kind of dozens or maybe a few hundred qubits, which is like the state of the art today. You just can't. So there, there are good systems learn on, build out the software stack, get people to try stuff. So I encourage that, but we just need to get bigger hardware scale faster.

It needs to be good quality, good fidelities, good error correction schemes that work and all that kind of stuff. But I feel like that's what's really holding us back. And, people have been saying for the last 20 years, we're 10 years away from quantum. And I honestly don't believe we're still 10 years away from commercial value at scaling quantum.

It's probably 5+. And I think that if we could fast forward to get to larger scale, then I think all of the innovation around error correction, and application, and inventing new things would just start accelerating, that pace of innovation would accelerate.

And right now it's just being held back by the scale of the systems that are available today.

Julian: I think that the main blocker is talent and people and knowledge. So I don't think that – we already discussed that. One of the typical things company do first is set up a small team and it's going to be relatively small teams. It doesn't have to be huge team. So I don't think money necessarily is the biggest operator.

We recently did a survey amongst 850 companies and a whole bunch of in-depth interviews which was really about this journey. Like what kind of steps do they take? And typically that starts with, a few people in the team trying to explore or figuring out some first use cases.

And start to build out a bit of an ecosystem, finding partners, and then moving to some first proof of concepts, trying to implement something and try to learn as much as. Maybe get some level support and try to adopt to it into our roadmap and then slowly experiment, by experiments, to build along the road and move towards scaling up some of the use cases.

Olivia: I think, you know, I agree with both Rob and Julian. I don't think it's necessarily engineering or money that's holding us back.

And I think we've been able to hit and meet every single engineering roadblock that we've encountered so far. I think if anything, what's holding us back is just time and the promises that people have been making in the field. The hype – I think so to speak. I think has been holding us back somewhat because no matter how brilliant we are and how many intelligent people there are in the field right now, we still need the time to meet these challenges and to overcome them.

And so I'm very anti-hype because as excited as I am about quantum computing, I think we have to be realistic about the time it takes to accomplish certain engineering feats. So I would say that I think maybe hype is holding us back because Julian just mentioned, we really need the talent and the knowledge to join us in the field.

And I think this sort of double-edged sword about hype is that it attracts the wrong people to the field and sort of pushes away the right people, has been something that I've experienced.

Ollie: So let's dig into that people problem.

How do we do this? How do we get people up to speed? How do we accelerate a process of, for example, you're doing your PhD. I'm sure that took an awful lot of time and effort.

So how do we get people up to speed, maybe a little bit quicker? How do we get people entering the space in a way that they can maybe be adjacent and then jump in? What would you say? How would you start that educational journey? I would say.

Olivia: Well, I would start it by recognizing that it's really, it's a generational problem. So this is not something that we're going to solve overnight or in the next year. I think whenever we talk about education and I sit on the board of the national government initiatives, we talk about getting people involved from a pretty early age and using quantum computing as a bridge to STEM education as a whole.

And I'm very passionate and I love STEM education. I won't get into that too much, but I think, we can start at the middle school, high school age by showing people how cool technology is and using quantum computing is just an example of that. And in terms of getting people involved who are a little bit more mature, advanced, I think, you know, I'm excited to see where these bachelors and these master programs that I already mentioned will go.

When I was in graduate school, when I started graduate school, like eight years ago at this point, that wasn't like an option. Like I didn't have the option of going to go get a master's degree in quantum computing. I did my PhD. It took some years. Some people say we don't have six years, we need people to fill these jobs right now.

It'll be really interesting to see the kind of graduates that these master's programs produce. It's a little bit too soon to say oh, they're going to be super successful in the answers to all of our problems, but I'm very optimistic that the people that come out of these programs will be able to hit the ground running and contribute a lot to the necessary sort of talent holes that we have right now.

Ollie: So, from Julian's perspective, you've got an awful lot of talent within your space. How do you begin to sync up those lines so that you can create a pipeline of your own, of people that maybe aren't coming from a science-y background?

Julian: Yeah. So I think this gets back also where we discussed a little bit earlier, right? I get the number of PhDs that we'll need to in hardware development or someone's very deep physics stuff. I think that's not, that's also limited at this point. I have some friends that are in, for example, string theory, trying to get into quantum and that's not easy because companies like Atom and IBM can cherry pick from amongst the best people, right? Because that group is not that big.

But the group that we will need to that has like a much wider knowledge, that will be very big. And in 5, 10, 15 years I guess we will need millions of people that will be educated. So, we must make sure that we will start very early, maybe not just high school, but even earlier, primary schools to get some basic foundation of maybe physics or STEM or even quantum physics. And for us, that's also a funnel, right? Like a small number of people that have really focuses on the deeper type of quantum algorithm. Things like optimizing algorithms and building new algorithmic parts and those kinds of things, and a much wider group that we try to engage, try to get enthusiastic. And they try to get enforced and nurture their talent and so that they can really help to identify the opportunities, couple it too with their domain knowledge.

Ollie: I'd like to understand the light point of innovation around the space. If we're talking about people coming in and ways that people are going to be using this. Like you're in the research space, you're really helping people build out both their capability and that understanding.

Where would you say that people should be looking that they may not know about yet? That quantum could potentially help them? And, where I don't want to ask where they start with that. I want to ask, where could they see further opportunity with something, things that they potentially already have in the works that you think could help accelerate things?

Rob: Let me answer a slightly different question. I think maybe building off the last question, which is like how do people get involved and where do they get started? And I'm coming at it from a building quantum computing platform perspective, not how do you use it, not the use case of the application so much.

And when you think of about like, if someone from a career development or career path perspective wants to get involved in quantum because it's this big kind of generational paradigm shift in computing performance, it's exciting. And people want to get in early, like how do they do it?

And there's the kind of the natural path, which is we'll go get a physics PhD and learn about quantum physics and how do you control lasers and RF tones, and all that stuff that we need to do quantum states and all that, but there's also these other disciplines. We talked about software engineers. We talked about electrical engineers and all that. Because there's so many more jobs in all disciplines that are required beyond physics. I think that's one way for people to think about how they might already have skills and experiences that apply to the quantum market, even if they're not physicist.

And for example, our control system that control the lasers are basically software defined radio controls that send RF tones. It's very similar to, if someone's building like a cellular base station: the architecture, the types of signal processing the devices, the chips that we're using and all that are all kind of one and the same.

And so, there's tons of people in the telecommunications industry, building systems like that today, and have lots of experience. And those skills and experiences are applicable to quantum computers as well. That's one way to get them all software engineers. So if you know how to write code and program in Python and programming APIs and compilers and schedulers and databases and all that stuff: we need that in quantum computer too.

And the interesting thing is that there's a lot of people that have interest in physics, maybe a background in physics, but their experience and their job histories and something other than physics. Those people tend to find us. A number of our software engineers also have physics undergrads, or just an interest.

At Atom, our vice-president control systems, she actually has a physics PhD, even though she never did physics as a job, she's been an RF, a control systems engineer her whole life and an engineering leader. But she has an interest and some background that makes it easier for her to learn the quantum side and apply, you know, her skills and experience to our systems.

And so that's where I'm coming from. If people from a career path want to get involved, there's ways to get involved. And there's lots of skills that are required in quantum beyond just the core quantum physics itself.

Julian: So maybe one thing that I heard Olivia and both Rob say is that…So quantum computing is pretty hot right now. And it's for X amount of people, but we can really use it as a lens to get people interested in all kinds of related things as well. Engineers being involved in quantum technologies but using their skills properly; for us as well to have people interested in quantum technology really explore a very cool new advanced AI type of things which might be important and applicable for quantum algorithms as well or quantum circuits.

So I think that's an interesting perspective that it's not just to… Now that will try to get quantum knowledge or quantum scales, but that we can use quantum technology because it's so hard to drive people into related fields as well.

Olivia: Yes. I totally agree. Quantum education is STEM education. And the more people that understand technology, the better. Not every single person that we engage with from a young age is going to go into quantum computing. That's totally fine. Some might just think it's cool and choose to work on a different type of technology or different fields or medicine. I think the more people that are engaged with STEM, the better.

Ollie: And on that basis, I think we need a bit of grounding, right? So there's a lot of hype in this field. There's a lot of marketing speak. There's a lot of "this is the future." But one of my favorite questions to always ask people when we're dealing with a medium that's in its discovery phase and is finding its steps is: what's the thing that you hate to hear in a meeting when you go in and people are like, "oh, we should do this around quantum?"

Olivia: This is big one. But this is a giant pet peeve of mine, but people who say we should put quantum computers in cell phones. I'll preface this by saying this was not in any particular meeting. This is just like something that I see on Twitter and LinkedIn. But I've seen it from companies, not just like heightened men.

Rob: Yeah, actually, I have a list of banned words on the wall next to me that are like my pet peeve things – that make me cringe when I see them out that other say. But the one that kind of maybe rubs me wrong the most is when people say let's make quantum real or we're on a path to making quantum real or something.

Quantum is real, it exists in the world. We're just trying to figure out how to harness it for computation. And these things work, they are real. They're just not big enough and useful enough yet to have a lot of commercial value. But when people say it's not real, I think that lens, it almost plays into this whole hype thing that's like we're selling snake oil or something like that.

And I'm not saying everybody out there is straightforward and there definitely is hype, but it is real. It's just that we've got to make sure that it's really useful, moving forward and that's really the mission.

Julian: Actually I had in my mind, both what Olivia and Rob wanted to say, not if they both took it already. So the first thing I wanted to say was that people think of quantum computers as just super computers that are doing everything faster and then particularly around very big data problems.

And I understand that because it's heavy compute problem, but it's just doing very simple, big computational problems. It's just not an easy use case or not a use case. And at the same time, indeed that what I often hear is that people say, this is just science fiction, right? This is very far out there.

And I don't think it's science fiction. You can program these things. You can run something on actual concept hardware. It probably doesn't do much, but you can do it right away, you can log in and you can send something. and just the fact that, it's already available. I think that's already pretty amazing.

So a bit of both. On the one hand, it's small and we've got to be modest and patient at the same time. Do not let that distract us or delay us in starting to develop these things and starting to build software because you can already write software, and algorithms and everything today. It's just a matter of improving that and waiting through the hardware.

Ollie: I'd like to drop things down to the personal level for one question. Give me one question which will be, what are you most excited about here? What's the thing that in the evenings, like you get home from work and you're like, ah, yeah, but I just need to look a little bit more into that, because that could be interesting?

Let me start with Rob here. What keeps you up at night over this stuff?

Rob: Yeah. I mean, what keeps me up at night, it's like the opportunity is so enormous. But how do you actually deliver on it? And so what gets me up in the morning and maybe it has. It gets me up in the morning is just this opportunity to really drive this next wave of compute performance.

Something that we really haven't seen, like this, maybe since, when people figured out how to do like network based computing and clusters and all that, and then it gave us this order of magnitude, The performance increased by using, many computers cable together in a fabric – like this is that kind of thing, that's coming.

And how do we accelerate that so that it becomes, it gets here faster. And then from a company building perspective, which is what I'm doing personally, is how do I build a company that can be a leader in that, and actually set the pace for innovation in that industry. At least at our layer of the cake, which is the hardware platform layer, and then we'll partner with others in software and cloud services and all of that.

So those are the things that get me up in the morning and I'm really excited about.

Ollie: Olivia.

Olivia: I have two. So one is a technology answer and the other one is a people answers. So the technology one I'll go first. I think one of the coolest things about quantum computing, and I'm a physicist on bias, is that we can use quantum computers and the quantum technology that we're developing now to learn more about the reality of nature and quantum mechanics. And the measurement problem for instance, is something that like, we still don't have understand.

We don't have a picture for us. And I really do believe that we can use the quantum technology that's being produced now to learn more about the physical world. So I think that's super interesting. The other thing that really motivates me is the fact that I think we're democratizing this field of technology to the absolute best of our ability.

IBM has quantum computers. Other people have quantum computers that you can access from literally anywhere in the world as long as you have an internet connection. And this is not true with almost any other emerging technology. And I talked to so many people from so many different backgrounds, people from all sorts of, parts of the world.

I talked to people who are not represented very well in STEM and in those sorts of careers who are so excited about joining the field and becoming part of the second quantum revolution. And I don't know… To just be at the forefront of it and be able to give people advice and to help people get to the stage where we are all out in our careers right now, I think is incredibly rewarding.

Ollie: Julian.

Julian: So I think that Rob gave a bit of a technology answer and then Olivia, a bit of technology and people answer. So let me try to give a little bit of application answer. And I think the world is increasingly computable, right? Everything is computed. Then there are so much compute power that will be required for almost everything.

The idea that we will have, for a very generic number of problem, they can use quantum computing and speed things. Not just if you a few percent better, but hundreds of times or quadratic, or even exponential speed ups, I think that's extra, incredibly exciting.

So think about a world in 10 or 20 years. It will be governed by quantum systems that can, maybe have personalized medicine on the spot or maybe sustainable products and energy creates and batteries for electric cars. I think that we can use quantum system still for such a good and sustainable cause. I think that's also very exciting.

Ollie: Thank you all for your amazing answers. So my last question, big important one. We like people to walk away from the show with something that they could maybe action or try could straight off the show, maybe someone's running or they're coming home or they're on the train home.

And they're thinking about "oh I'd like to I like to start on this a little bit and see where I can feed it into what I do." What's a resource that people could look at first?

Olivia: Without sounding too much like an advertisement, like I really do think the Qiskit textbooks is a great piece of information, the Qiskit YouTube channel is great. If you prefer to watch things, in a visual setting, a lot of people really like that. And another textbook that I would recommend is by Thomas Wong that he published just a few months ago.

I think it's an excellent introductory textbook, and it's on Amazon, and it's not expensive. And I think you can actually get a free PDF online.

Rob: I'm also a fan of Qiskit university. There's a lot of stuff online there. That's great. So thanks to Olivia and team for putting that together. We use it internally to educate people and point customers that way. I'd say in addition to that there's a number of conferences that occur throughout the year in different parts of the world.

And the United States in different states and so forth. And that's a good polite place to come out and meet some of the folks like Olivia and me that are in the industry and talk to us about what your problem statements are and what resources are available and meet people and get engaged from a human perspective as well.

So you might want to check some of those out.

Julian: There is a lot of stuff on the internet now, today. So I'm sure, you can just Google then there will be stuff so fine. I think it's most for just challenging yourself. What is interesting? Where do you want to dive deeper in?

How does it work for your business? Where do you find large computational problems? And then just Google and search a bit if that has been thought of before. I think it's really driven by curiosity. So I think that's the main thing. Just be curious and try to explore, and then I'm sure there'll be a lot of interesting things.

Ollie: With quantum, the future looks exciting as we apply this complex and lightning fast computing power to some of our toughest problems.

The future in business will hold more opportunities than ever before. A big thank you to today's guests – Olivia, Julian, and Rob. If you've enjoyed this episode, don't forget to subscribe on Apple Podcasts, Spotify, or wherever you find your podcasts. This has been Future Sight, the show from Capgemini invent. We'll see you soon.

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