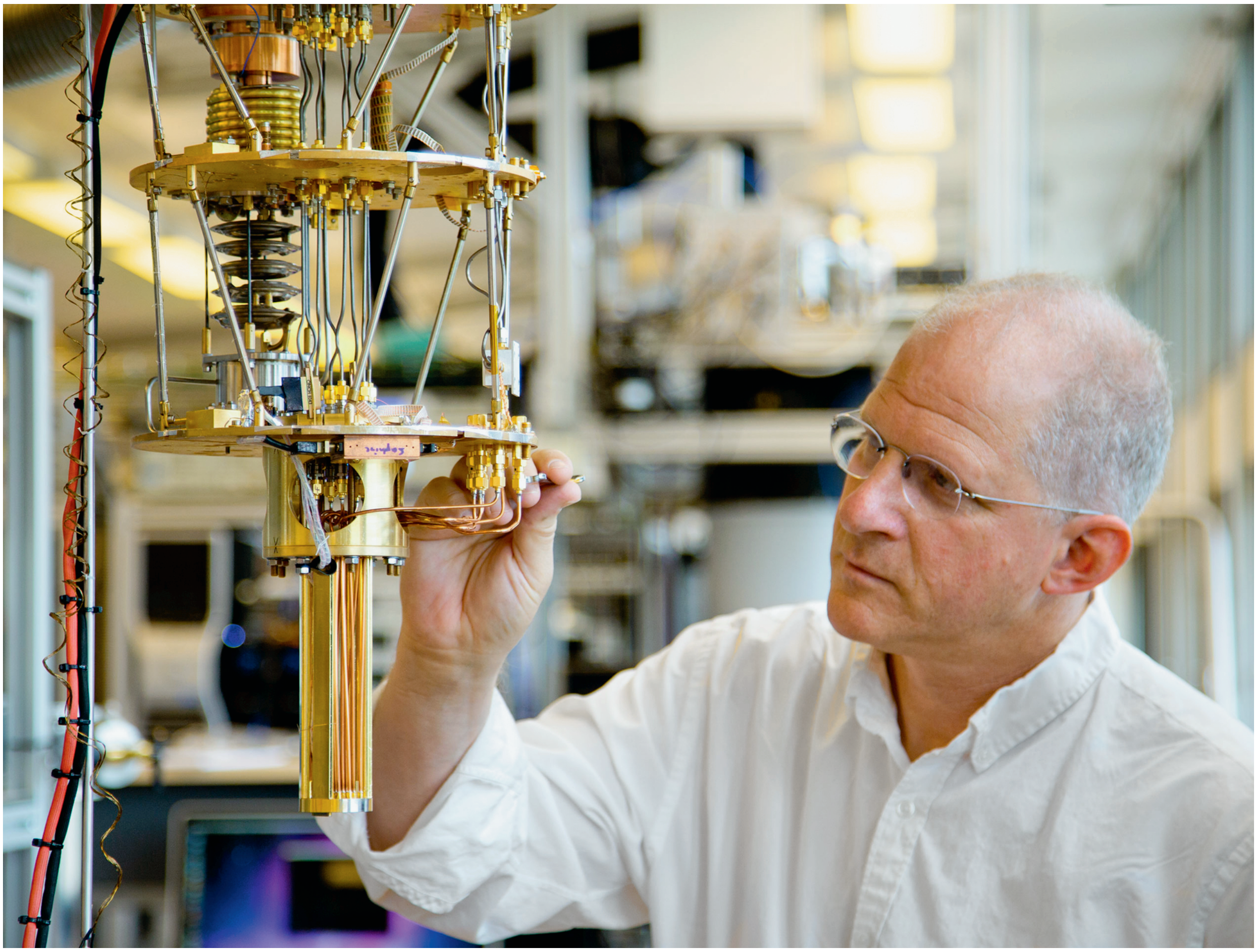
Charles Marcus in the laboratory.
Photo: Ola Jakup Joensen, Niels Bohr Institutet.



KAPITEL 25
Professor Charles Marcus

Charles Marcus's office is less than 200 meters away from my own, just across the lawn of Universitetsparken, in one of the wings of the old H.C. Ørsted Institute building. Here, his Center for Quantum Devices, or QDev, occupies more or less a whole floor. The center holds almost a hundred people, comprising university and Microsoft researchers, students, engineers and support staff. Despite the fact that this is something as uncommon as a university-Microsoft amalgamate, the halls look as grey and worn as anywhere else in the building. But Charles Marcus's office is a friendly looking place of nice bookshelves, photos, and well-worn Danish designer furniture.

I aspire to learn at least as much as I teach

In a way, it is easy to interview Charles Marcus because he talks a lot. The challenge is to remember at the end of a long and fascinating answer what my question was, and whether he actually answered that or something else. But my first question – what the aim of his research is – goes rather well.

> "The aim of my research is to take known, or partially known, laws of physics in the context of quantum mechanics and use them for new ways of controlling and processing information. There are surprising connections between information theory – that is, how you encode and transmit information, how this cable here can transmit gigabytes per second of information – and quantum physics. Why would it be that the laws of quantum mechanics seem to provide mechanisms for information control and information processing that are better than, or at least different from, those of classical physics? Nobody knows why, but it's a very interesting connection, which not only has a fundamental character, but also an extremely practical one. There are problems in science and engineering that cannot be solved with computers – well there are a million examples of problems that can't be solved with computers – but there are hopes that if computers were based on the principles of quantum physics instead of, as now, those of classical physics, then perhaps some of those problems could be addressable. But my interests are not, principally in solving those problems, but in fundamental physics and how that relates to those problems."

In practical terms, addressing this aim translates to designing and studying a wide range of experimental systems, usually nano-fabricated, and measuring their properties at temperatures very close to absolute zero. All so that these quantum systems can be used for information processing.

> "As objects get smaller and colder, they maintain quantum mechanical coherence for longer. There is some corner of the relationship between cold and small and time where objects can behave like quantum mechanical systems (Facts box 1), rather than classical systems, for long enough that you can manipulate the information inside of them. We build such systems using nano-fabrication, measure near absolute zero and try to encode information in these quantum systems, manipulate it, and take it out again. Hopefully we can eventually integrate this into larger and larger systems until some day, we may have a chip with a whole computer on it, a computer operating in a quantum mechanical way."

As alluded to above, Charles Marcus wears two hats: he is an academic and he is a Microsoft employee. In the first role, he teaches, and in the second, he tries to build a quantum computer (Facts box 2). Of course, these roles cannot be separated, and both of them are carried out in the setting of basic research.

> "If I were 100 percent an academic, I would say that 100 percent of what I do is teach, whether it is here or in a classroom. Now I am apportioned between a corporate life and an academic life, but frankly, I am kind of teaching all the time anyway. As long as people in the lab are younger than me and haven't been on the same walk that I have, I'm teaching. But I aspire to learn at least as much as I teach. So there is a lot of learning and teaching going on, and the research is the medium in which that exists. The tension we are playing with on a daily basis is that between the research as the medium in which the activity is carried out, which I think is what academics do, and the research being the point of the research, which is what technologists do."

It does feel to me that physics is an entry port to the truth

So far, so good. The next thing I normally do at this point is to ask the person across from me to talk about which papers or other accomplishments he/she is most proud of, and why. That tends to be a good place to start a discussion about what excellent research is.

> "I moved from Harvard to Copenhagen for the express reason of shedding the notion of personal

What is quantum mechanics?

FACTS BOX 1

Quantum mechanics is an extensive set of principles and calculational tools that provides an understanding of how nature behaves on a small scale – the world of atoms, molecules, and atomic nuclei – but also how nature behaves when those materials are combined to form materials – metals, insulators, superconductors, semiconductors – as well as how electromagnetic radiation, like light, behaves when it interacts with matter. Says Marcus, the principles of quantum mechanics are not very intuitive, coming from observations of the classical world, and include ideas that quantities like energy, momentum, even light and matter, come in discrete units. To some extent we do accept this. Flowing water looks continuous, but we accept now that it is made from discrete molecules that are all identical. The same with light, energy, and everything else: the world is quantized – it comes in discretely sized packages. But it's more complicated than that. What the package is depends on the measurement that is performed. And we are not used to that – that something does not have properties on its own but only has properties, for instance, once it is interrogated. Before that, it doesn't have the property. We may say "my keys must be somewhere!" But on an atomic scale, that isn't true. And it gets stranger still. The outcome of measurements seems to be probabilistic. Is the object here or there? Answer: with 50 percent probability it is here, and with 50 percent it is there. But what determines which outcome we find? Answer: It's just chance. It's like God, playing dice. That seems to be the way the world works.

Wrongheaded as it sounds, these principles are not only valid when compared to experiments, but they are needed to understand the everyday world – why a candle gives off light, why metal is shiny, why red paint is red. All of those effects can only be deeply understood by examining them in a quantum mechanical framework. In fact, says Marcus, it is classical physics that no longer works except as a very useful approximation or model. But some aspects of quantum physics have not worked their way into technology, despite the fact that it is now a one-hundred-year-old viewpoint, with essentially no doubters. The technology of controlling quantum systems, not just describing or measuring them, is at the frontier of the field. Putting the unintuitive aspects of quantum mechanics to work for us appears theoretically possible, but technically difficult. Not impossible, just difficult.

pride. It is a dangerous characteristic, and I was beginning to detest it in myself."

Why did you think that moving here would make you shed that?

"Well, it's not the answer to the question. What I'm saying is, I'm refusing to take the bait on what I'm most proud of."

I hear that, and I find it interesting. Well, perhaps we can return to that later. Okay, pre-Denmark then, what were you most proud of and why?"

"I think I am most proud of the young people who, under my guidance, decided to choose to be scientists for their career and have now been, to varying degrees of course, successes in the world of scholarship, and with whom I am still friends. The transformation of kids into colleagues. The work I do is to guide young academics to carry out the work. The last time I touched one of those knobs in there, the last time I even got close, they yelled at me not to do it. That's my relationship to the apparatus. If I touch it, I have to do it surreptitiously or else I'm going to get into trouble. I am proud of instilling in those young people a sense of ownership, so that they don't say, "Charlie, what should I do next, but Charlie, don't touch my apparatus. Get out. It's mine. You, out. And thank you for the lovely idea. By the way, it was three quarters wrong, but I corrected it." Then I can say to myself, well at least it was one quarter right; my gift was that quarter. And when they take ownership, correct the idea, and come back three weeks later and say this is the correct idea and this is what the data looks like, then I think to myself, I did my job."

I try again. "Just briefly scanning your CV, I see some papers that have been extraordinarily highly cited. Science-wise, those are not necessarily what one is most proud of. If we think in terms of scientific accomplishments, which would you pick?"

"We could play Jeopardy where, you know, you state the answer and I have to come up with the question. So, you could say, to which question are these highly cited papers the answer? If I have to come up with the question for that, I would say, is there a record of your pleasure? Is there documentation of your enjoyment? I think most of us have our most pleasurable moments in undocumented situations, and those papers stand as the exception to that rule. They are like the photographs that you took on your honeymoon or on some great vacation. You look back over those pictures and you think of whatever the thing or feeling is that the pictures stand as a memento to. I would say that with each of those papers there were moments of joy when ideas came together and the data matched and all was clear. These papers are the record of those experiences, the clearing of the fog in the company of others, a shared joyous experience. Irrespective of whether the paper is highly cited or not, and indeed some of my favourites are way down at the bottom if you sort them by number of citations."

So the ones that you would pick out, what do they share, apart from such moments?

"If you do sort the list by citations, then I think the one at the top is from 2005 when I was a professor at Harvard; the second is from when I was a graduate student; and the third, I don't remember, but the point is, there is no particular pattern and they are from different eras of my life. I just think that each one of them had that kind of specific moment, a particular spark of pleasure. Like when you solve a jigsaw puzzle. To be experiencing that in the lab, it's a slightly bigger scale but it is still that same kind of pleasure."

Are such moments the reason you have this job rather than another one?

"There are a few answers to that, and that would be one of them. Another is that you have a feeling that the things you find are true for all times. They are not subject to fashion or whim, they're just true, and in this world in which truth seems to be, bendable or commoditized or less rigid than I might like, it does feel to me that physics is an entry port to the truth. I am not so open minded about truth that one person's truth can contradict another person's truth. I'm more along the lines of one of them is wrong, at least in the domain of science where I'm comfortable. There are other branches of scholarship where such disagreements are probably the engine. But in this discipline, there is this notion of buried truth, and uncovering those truths, I think, can be a rewarding life."

Close friendships have been an important part of Marcus's scientific life. I feel compelled to say this now to put his, to some perhaps rather outlandish, answer to my question about what drives him into perspective. The friendships we will return to later.

"Making career choices one generally thinks of choosing between, let's say, making money, or helping people, medicine, for instance. I was less concerned with people, I think, and maybe this is a linking element among participants in the hard sciences, or at least physics. We physicists tend to have an intimacy with inanimate objects. We don't reserve those feelings for people. We find these ideas and data and the inanimate objects and concepts that we work with on a daily basis to be really rewarding, and our relationships with them really intimate and that is another driver for me. It is very important that you are sharing a communication with other people who were also participating in the creation of the ideas. But your relationship to those beautiful ideas stands on its own without other people involved. And that feels to me like a well-lived life."

That Charles Marcus is driven by the beauty of the ideas themselves does not mean that he is not aware of his role in society, or of the potential ethical pitfalls that scientists face.

"We tend to get rewarded for publicizing our work to a general audience and that requires us to make choices. For a general audience, the subtleties of what we do can get lost, and the reward is bigger if you can tell a linear story, such as we solved the energy crisis, we cured cancer, or other oversimplifications. So, the ethical issues involve balancing complexity and clarity. A part of this is that being dispassionate as a scientist is tricky, because the data doesn't just jump out of the machine and land on your desk; you have to select that which is telling you the right story. But what does that mean exactly? We constantly have to ask ourselves, are we oversimplifying the story? The only thing we scientists have to give to the world is a straight story. So those are choices that we make, and I think about them every day."

Frat boy behavior and other mysteries of the universe

One of the aims of these interviews is to extract what constitutes excellent research, and my hypothesis was that it would be possible, by talking to these 25 leading scientists, to reach a more sophisticated understanding than "I know it when I see it". For Charles Marcus, it has a lot to do with picking questions that have the right balance between too simple and too complicated.

"So where does the magic come out? It's really hard to describe. What I can say is that there is a boundary between complexity and simplicity, and if you are right up against it, you can make a guess at what is going to happen in an experiment. If your guess is kind of right and you see that from the data, then you can begin to flesh out a little bit what is going on. There are many areas of science where you essentially know the answer before you start. I am not sure I would even call them science, but they go by that name and they publish in science journals. The experiments can be super complicated and you have to get the apparatus just right. And if it doesn't work you say, "Oh I must not have gotten the apparatus right, because I know exactly what's supposed to happen". And you tune it up, and finally you say, "Ah, now it worked perfectly", and you

What is a quantum computer and what else does QDev do? **FACTS BOX 2**

The Center for Quantum Devices (QDev, for short) studies how to create and control quantum mechanical coherence, that is, the quantum state of a system before it is measured. The focus is on quantum coherence in electronic systems, meaning that electrons in devices, the carriers of electric current, behave like a wave and can show interference and, even more interestingly, can show a distinctly quantum mechanical property called entanglement, when the quantum wave describing the system can be separated across space (small distance, across a "chip," but still separated) and a measurement in one location creates a correlation with the outcome of a measurement at another location. Entanglement is not present in classical systems and is considered the key property that enables quantum computing.

A quantum computer uses quantum coherence and quantum entanglement to allow a new type of computer algorithms to work on a computational problem essentially in parallel, where all the coexisting states ("zero and one at the same time") of an unmeasured quantum state exist at the same time and all can participate in a computation in parallel. No one has built a practical quantum computer, but many theoretical blueprints exist, and the challenges are being addressed in many university-, government-, and industrial laboratories around the world. The primary challenge is preventing measurement, which happens whether the result of the measurement is written down or not. Measurement destroys quantum coherence and must be kept out of a quantum computer. If there is any detection of the internal state of the computer by the outside world, the quantum magic is gone. Once entanglement is brought under control and becomes a resource, the technological harvest has the potential to revolutionize communication, information processing, and simulation of quantum mechanical systems from novel superconducting materials to biomolecules. To investigate quantum properties of electron systems requires miniaturization and low temperatures, and much of the experimental investment in QDev is toward those two needs: nanofabrication, and refrigeration to a few hundredths of a degree above absolute zero.

QDev also comprises theoretical physics. Theoreticians work with experimentalists to predict new effects, design devices, and understand data emerging in the lab. Charles Marcus was the first director of QDev, from 2012 to 2020. In 2020, for the second phase, theoretician Karsten Flensberg has assumed the directorship of QDev. Representative QDev papers are, in topological superconductivity: [93]; materials science: [94]; spin qubits: [95]; and theoretical physics: [96].

can be proud of yourself for having set up the apparatus, but not for having discovered anything because you already knew what it was going to be before you even started. I think you need to avoid those kinds of problems. Like I described to you in the beginning, the interesting things happen if you pick a problem that is rich and deep and complicated and involves many agents interacting with each other which renders their behavior unpredictable. This could be a problem in everything from sociology to chemistry. You can't predict what many things do when brought together. Who would guess that perfectly normal young men, when put into a fraternity house would behave the way they do, you know? It's this surprising emergent phenomenon. Each one of them seems decent enough. You couldn't have guessed it from having one boy over for dinner, he seems perfectly civilized; he asks to pass the salt and so on, and then you put them in this house and madness occurs! It's the same thing in physics. The individual elements of something can be simple enough that you understand them, but then you put 5, or 10, or 50 or 10^{23} or whatever together, and some phenomenon emerges that is a total surprise. And, I think that there is excellence in when you guessed right about what it was that led to the emergence of a behaviour that was not evident in the constituent parts. To me, that is where interesting science lies – in the emergent effects when simple elements are connected. These are the kinds of problems that I aspire to, that I target myself toward."

There was a time, which we will return to shortly, when Charles Marcus got himself into a problem that was too much on the complicated side for his taste, namely, neuroscience.

"I'd love to have made progress in understanding the biological origin of consciousness, or the biological origin of mental illness, it is thrilling to think about. But I eventually drifted away from that field, not because it was uninteresting; in fact, it was maybe too interesting, in the sense that I didn't think that one would ever be able to connect across the range of brain science all the way from cognition to neuron. That seemed too far. So, I became pessimistic that within my lifetime I would see the rewards. In physics it's easier to find problems where the individual elements are simpler than neurons, and the emergent phenomena are correspondingly simpler. No less surprising but simpler. And you can make progress and they're fun."

He was an amazing teacher

Before I started this project, I fully expected to hear many people point out a wonderful high school teacher as their original source of inspiration. Very few did, but Marcus is one of them.

"I have a great photograph to show you, from a few months ago. It's a picture of me with my high school physics teacher. Sadly, we look more similar now than we did at the time. But he's still teaching high school physics and, man, he was a masterful teacher, and I was a very good student. That interaction between an engaged teacher and a hungry student, really made a lifelong bond. It's been 40 years now, and we are still in contact."

Charles Marcus' mother was a neuroscientist and psychologist. His father was a salesman. Physics was, as he says, his own invention.

"I don't know whether it's true for all scientists, but I can't exactly remember a time when I didn't want to be a scientist. It always seemed very obvious and I declared physics as my major when I was a freshman in college at Stanford and just stuck with it. You know, in some ways my story is boringly linear; I knew what I wanted to do. I had my fun in college I would say, but a lot less than I wish I had. When I look back at those years, I think, why did I work so hard? Maybe it was overkill? All my friends teased me that I was always in the lab and they never saw me. But I wasn't unhappy; I was very happy."

Stanford, Harvard, Stanford, Harvard

After being an undergraduate at Stanford, Charles Marcus went to graduate school at Harvard. That was, as he phrases it, a little rockier. The summer before starting, he got an offer to join a research group and did so without a lot of forethought.

"I did it without taking really seriously the degree to which those early years in graduate school can determine or at least strongly influence who you become. You know, think back in your own life. You make these coin toss decisions and the next thing you know, that's who you are. So in my third year of graduate school I was on my way to becoming an experimental low temperature physicist – ironically, not unlike what I am doing now – and I thought, I'm not enjoying this. What is wrong with me, why can't I get into this? Notice how I formulated the question; what is wrong with me? Only later did I recognize that it was just not a good match, and in that third year, I left that lab, sending me back to square one."

That was when he started thinking about neuroscience or more specifically artificial neural networks. There is a thread, of course, to his current work, in that this is also a sort of information theory problem, only inspired by neuroscience instead of quantum physics. And although he worked with artificial neural networks, he also started thinking a lot about biological neural networks. But at the end of graduate school, he changed directions again.

> "I had this kind of negative epiphany at that time. I was doing theoretical work, and I didn't think I was particularly good at it. I had a lot of ideas, but I was not very good at carrying them out. Did you ever see the movie called American Splendor? It is about a comic book writer who wasn't a very good artist. He had great ideas about what the comic book should be, but he couldn't draw, and he was frustrated by that. I was like that in theoretical physics. I knew exactly what the interesting questions were; I just couldn't calculate the answers! So, I thought well, that first thing I did, even though I really didn't like it, I was very good at it. Maybe we could hybridize these things and find something which I both like and am good at. You know, Americans get raised with a mythology that is different from that of the Danes. We get raised with the idea that we can be anything we want, and this was the first time in my life that I kind of looked in the mirror and said, "Ok, you can't really be a good theoretical physicist; you just don't have it.""

Because of that conclusion, and an act of generosity from his PhD advisor, who let him stick around and change fields, Charles Marcus went back into the experimental laboratory and spent the next two years as a postdoc doing semiconductor physics at Harvard. After that, with zero experimental publications, he got a professorship at Stanford.

> "I gave a good job talk! And, you know, it was great data, it was a great idea and they trusted me and it worked out. I built a lab and I got tenure. Seven years later – well, seven years and a girlfriend who later became my wife – I'm focusing on the academic trajectory of my life, but there were one or two other things going on. Anyway, seven years later, around 2000, there I was 38 and a tenured Stanford professor, a condensed matter physicist, not unlike what I am doing here. Here is a picture of me from that era – I was still actually doing experiments myself. And my wife – no, she was still my girlfriend then – had had a baby. There's the baby right there, who became that child, who then became that young person who is there, who then had a sister who is here and they're having an argument in their Halloween costumes about which costume is better, a pretty heated argument. And then I got a call from Harvard saying, why don't you come back."

Harvard wanted to expand the research area Charlie Marcus had developed at Stanford. They were building a large new physics building where he would be located and which he would be involved in designing. All of this was too attractive to turn down. He took the offer and returned to Harvard.

> "When I was a graduate student, I had certain heroes at Harvard. One of them is the guy in this picture, Bert Halperin, visiting me in Copenhagen. I'll show you something funny. Here are my notes from his class when I was a graduate student, still in perfect condition, and here's me as a graduate student at Harvard. He was a real hero of mine; I learned so much from him as a graduate student, and then I came back and we became very close personal friends. That was a really nice transformation, from seeing a professor as a hero to becoming personal friends with him."

What was it about him that made him your hero?

> "It was the ratio of how smart he was – he knew everything about everything – and how modest he was. He never directs the discussion toward himself and his accomplishments. And yet, in his quiet way, he is a paragon of information and

insight that makes him a world treasure. He is revered by all physicists; he is known throughout the world. Without ever bragging. He just did it right, he just did the right work, said the right things, had the right ideas, and never shined the light on himself. That is why."

At Harvard, Charles Marcus became a professor in the Department of Physics and was closely involved in the work on the new science building. A Pritzker Award-winning architect, Rafael Moneo, was selected for the project, and again, they became friends and worked closely together. He found the process fantastic: the architects actually wanted to know everything from how scientists work, to the size of the chalkboards and the location of the coffee machine, and as a result, the building became a spectacular place to do science. In 2004, he became director of the Harvard Center for Nanoscale Systems, of course located in that building, and served in that capacity until 2009.

"And maybe I felt a little bit like that chapter of my life had run its course. I'd been a graduate student and a postdoc and a professor at Harvard, I've walked around Harvard Square 200 million times; I've enjoyed all the adulation of being a Harvard professor; so I was over that. It was fun but, I felt a little bit like I could predict what the next 30 years of my life was going to be. It was going to be doing that. It was very rewarding, the students were smart, the colleagues were smart, but it was pretty highly predictable."

Copenhagen

And so in 2009, he came to Copenhagen, to the Niels Bohr Institute, on a sabbatical. He liked Copenhagen very much. When he returned to the US, he was offered the idea of coming back to Copenhagen and setting up his group there through grants from the Villum Foundation and The Danish National Research Foundation.

"And eventually I thought, well, why not? Let's say I move here and after 5 years I find that I just have to get out. One could have handled that by taking a leave of absence from Harvard for an extended period of time. But I decided that if I'm actually worth anything, I can get another job somewhere if I really don't like it. I always had in the back of my mind how I would do in a lab where you have to really work to build it up yourself. At Harvard, honestly, unless you're maliciously incompetent, the students pretty much take care of everything. They are so good that as long as you don't directly do damage to them, you can kind of fall asleep and everything will be okay. And I thought, well if I go there, can I get the fire going to the point where it takes off by itself again?"

So Charles Marcus moved to Copenhagen in 2012. And it was easy!

"People had told me things like, "This is the dumbest thing I've ever heard anybody think about doing in my life; you're going to quit Harvard and move to the University of Copenhagen?" Turns out, the kids were just as smart here as they were at Harvard. And it has been a success. Now the fire is going, I don't need to walk across the hall and tell everyone what to do, and they're having meetings that I'm not invited to. Then the Microsoft thing came. You are going to run out of memory, and I'm going run to out of voice, but that is yet another adventure, which started about a year ago."

What happened, in brief, was that Microsoft decided to make a very serious effort to build a quantum computer (Facts box 2). Charles Marcus had already been associated with Microsoft for 10 years at that point and was personal friends with Mike Freedman. Freedman is a Fields Medalist working at Microsoft who had come up with an idea of how to use certain topological properties of matter to encode information, ideas related to the quantum computing that Marcus was involved in. Several years of exchanging ideas led to the development that Marcus is now officially also a Microsoft employee, as are many of his colleagues in the center.

"That has been another big change. It hasn't changed for me on a daily basis except it's been a little more hectic. But it has changed around me, with a lot of people at the university having to deal with intellectual property rights, who owns what, and all these kinds of things. In a way it has been sort of a relief, because now the funding is stable, and the lab continues to thrive. Okay, all in all, that was like a forty-minute answer to a two-minute question!"

Thinking back on what we talked about before, has this new development changed your focus, from one of curiosity to producing something that is going to change the world of computers?

"A bit, yes, but not entirely. For that, I think Microsoft will have to hire people who are more naturally like that. First of all, I don't think that people can change that much, no matter what, and they surely don't do so in their 50s. I'm interested in the physics. And I think that we, meaning Microsoft in this case, have to hire some more engineers who can turn what we do into something a little more practical and then another group of system engineers who will figure out how to put that all together. I want to be like a bloodhound sniffing out interesting ideas."

I never wanted a work-life balance

How does one direct a research center of 100 persons, or perhaps more precisely, how does one even get to that point? Do you see any personal traits that have led to precisely you being in this situation and that continue to make it possible?

"Yes. I don't have a very balanced life. And it's not that I made some decision that because this work is so important I would sacrifice the otherwise highly desirable work-life balance that everybody strives for. I never wanted a work-life balance. Maybe that makes me less good at other things in life, like family responsibilities, but I don't think there is much I can do about it. Of course, I care about my family. But I think that there are people who really, at 5 o'clock or something like that, feel that going home is the right thing to do. That it's the right thing to do to divide your time between these many excellent activities, and I'm just not that good at it. We all have to admit our weaknesses, or whatever, our constraining characteristics, and for me this is one."

At this point there is a knock at the door. Charlie Marcus is supposed to be at a meeting, but negotiates exactly 11 more minutes. We continue and try to condense the rest of the conversation into the most essential points.

"So I really care about this stuff. I think I have empathy and can understand when people are upset in their work environment, and that I care. I believe that there are other people in the world like me, who want their work life to be one of the principal sources of rewarding happiness in their life. I can, under that assumption, provide that for them. I think that, because of the way I think about things, I make little decisions which, honestly, a lot of people around here find very foreign and maybe even a little offensive. But another trait that I have is confidence in myself, and enough confidence to know what is right and wrong at least in the world in which I have expertise. I think those are the three characteristics that I wanted to mention: that I am unbalanced, that I have empathy, and that I am confident."

The co-dependency problem

Given our limited time, I give Charles Marcus the option of either telling me more about what happens at QDev or outlining how he thinks the Danish funding system ought to be set up to facilitate research excellence. He picks the latter.

"The Danish funding system has to acknowledge that it is engaging in a – what do they call it, like when your spouse is a drug addict? – a co-dependency relationship with universities. The universities don't have enough money to do the things that would make them competitive internationally. There's this crème brulé of sweet money at the surface that comes from the foundations. It comes with all kinds of responsibilities, but it sweetens the pot for labs like mine, which are gorgeous. But if you go outside of this handful of highly funded laboratories, then things don't always look so great. There is a have-and-have-not situation here, which is not sustainable. When the cameras are rolling, and you go into my lab, you may think "Wow, University of Copenhagen, thumbs up!" But then after a while you start to pick up clues that the finances are not distributed uniformly. For example, where's the start-up package for a new assistant professor? The foundations are excellent, and I wouldn't be here without them, but they allow the university to continue in this unbalanced way. It's expensive to be a competitive university on an international scale. It is expensive to try to keep up with ETH Zurich [a public research university in Zurich, Switzerland], or Princeton, or Stanford, even in some little area. Yes, as it is now, many labs here can be as good as the absolutely best labs in the world. I think this is one of them, and there are several others. I'm sure you are talking to 25 of them."

What is the problem then? As Charles Marcus sees it, being an educational institution, you need the resources not only in the top-notch research labs.

"I'll give you one example. Instead of having a big, well-funded laboratory course room filled with equipment where students learn laboratory skills, they send the kids up to our research lab. This is like, inappropriate squared! It's like, inappropriate squared, for them to be dumped in a research lab, and it's inappropriate for the students here to be told, "oh, by the way, three first year bachelor students are going to come into your quantum physics experiment, can you find them something to work on?" And they're like, "what are you talking about? No! I have nothing to tell them about." So why doesn't the university have money for that teaching lab? Perhaps because educational labs don't have the right visibility for foundation support. Fine, then find another way to fund them, but it has to be taken care of one way or another. I think that the government, in a partnership, coordinated with the universities and the foundations, has to develop a plan to have strong funding across the board, glamour or not. We have to take care of the machine shop, the sports facilities, the canteen. If we do that, we'll send a stronger message to every young person: this is a great place, it's a joy to be here, count your blessings, rise to the high level this place sets. How's that for my answer? I have to go to my meeting!"

And with that, we say goodbye and I walk down the stairs and across the lawn, a little out of breath and wanting to learn more about quantum physics.

Professor Charles Marcus

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Education: BSc in Physics, Stanford University (1984), A.M. (1987) and PhD (1990) in Physics, Harvard University

Villum Kann Rasmussen Professor, Niels Bohr Institute, and Partner Research Manager, Microsoft Corp.

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