INTRODUCTION

Stephen Wilson is an associate professor in the Materials Department at UCSB. His current research interests are in quantum materials, and he, along with Professor Ania Jayich, is co-founder of the newly created Quantum Foundry. He got both his B.S. and Ph.D. in Physics from the University of Tennessee, Knoxville. He spoke with me (Xander Apicella) on Thursday, March 19, to discuss his life and his involvement in UCSB's Quantum Foundry, the first quantum foundry in the world.

INTERVIEW

Xander Apicella: Thank you so much for talking with me in the light of all the top and the coronavirus and everything. I really appreciate it—I'm sure this isn't easy to find time for.

Professor Stephen Wilson: No problem. No problem. It's just been a lot of administrative meetings about ramping down research and all of these contingency plans to promote instruction. Yeah, so it's been busy.

Xander: How much of an effect is [the coronavirus] having on research at UCSB?

Prof. Wilson: Research is totally stopped as of tomorrow. UCSB is a major research hub. I would say something like 80 percent of our time is spent doing research. It's particularly impactful on graduate students. If they can't get into the labs they can't get data, so there's a lot of strategizing on what they're going to do in the interim.

Xander: How long have you been actively studying materials and what's your focus of study?

Prof. Wilson: I study a category of materials that are broadly described as quantum materials. These are materials that have very unusual electronic properties which are driven by the quantum nature of the electrons in the materials themselves. That can range from very exotic forms of magnets to unusual electronic states such as unconventional superconductivity to other classes of materials that have topological electronic properties. These are materials that people are trying to look for—fundamentally new electronics states—that because of their unusual properties have far-term device potential: electronics using the spin of the electron—which is the quantum mechanical descriptor of its intrinsic magnetic moment—[and] unconventional superconductors. If you can make a high temperature superconductor you can do lossless power transmission, and things like that. So I've been doing research in those materials for—I guess since I was in graduate school—so that would be 18 years ago.

Xander: What got you interested in these subjects in the first place—was it a high school thing or did it come later like while you were studying in your undergrad?

Prof. Wilson: That's a good question. I kind of fell into it. I think I had a number of interests when I was an undergraduate across different disciplines. I was an undergraduate physics major so I was interested in a lot of different disciplines of physics. And then I ended up deciding to study what's called condensed matter physics. Within that subfield there are quite a few people who study quantum materials. My research advisor at the University of Tennessee was both growing materials and we used scattering techniques like neutrons and X-ray scattering to try and understand the systems.

Xander: How did you come to UCSB? What brought you here specifically?

Prof. Wilson: I was an assistant professor in the physics department at Boston College for about four and a half years. And then I decided to move to the Materials Department here at UCSB. First of all, that’s because there's world class faculty here in the materials department to collaborate with to push the field of quantum materials forward. But also, the core scientific infrastructure here for both growing and characterizing materials is unmatched by any other university I’ve ever been at. And that really is a key enabling factor for new materials discovery and new electronic state discovery. There’s this broad, university-wide commitment to world-class, open-access research and instrumentation and tools that students can use to push discoveries forward.

Xander: Yeah, absolutely! So I'm gonna dive a little bit into the Quantum Foundry because that's a huge interest area of mine and also I think people are pretty excited about it. So, when did you get attached to the whole project, and when did it start up?

Prof. Wilson: I think the NSF, the National Science Foundation, solicited proposals to form what they called foundries. So they solicited proposals for quantum foundries. I think that would have been in the fall of 2018—like August, 2018—when they had this broader announcement. UCSB is a very collaborative place, so a lot of people got together and tried to think about what type of effort, UCSB could organize. Both Anya Jayich and myself led the effort to put together what UCSB’s vision for the quantum foundry would be and how we would implement that. So that's when the process started. It was formally awarded in late September of last year. So that's when the start date was—it’s somewhat of a long process, it's like a year.

Xander: What will [the Foundry] be doing, what kinds of projects will be working on, and how will it partner with industry?

Prof. Wilson: I'll just start with the vision. At the federal level, there's a large investment toward what's called this national quantum initiative. And the NSF and other federal funding agencies have investments under that umbrella. The NSF first center-scale investment is the Quantum Foundry. There's a broad consensus that the next real evolution of electronic devices is going to come as people start to move into quantum based electronics. And in order to facilitate that type of next generation technology you have to—let's take a step back.

Quantum based electronics are electronics that transition to no longer just addressing a single electronic state: a bit, something that's binary or on or off. You start addressing a different object, the qubit, which is the superposition of more than one electronic state. There are fancier terms like entanglement and things but there are certain advantages of using this quantum bit which is superposition of two or more electrons. And the idea is, if you're going to make electronic devices out of these quantum bits—and be able to realize the theoretical promise of using quantum information instead of classical information—then you need to be able to make quantum bits that that you can create, read, write and store information on and have that quantum information not be lost.

We call that ability to keep the quantum information without it being lost coherence. If we lose that coherence, we call that process decohering. Once they decohere, the information is scrambled and you can't retrieve it. So the real challenge, and it's a fundamental challenge, is to find a robust way of storing this quantum information and reading it and manipulating it such that the coherence of the information is preserved. I think there's consensus that a major roadblock is the paucity of materials that you can use to build these quantum bits.

The fundamental challenge is to find materials that can host highly coherent quantum information or quantum bits. So currently in the field of quantum information there are many different possibilities—people are trying to propose different quantum bits that they think are the future. And there's not a consensus across the entire community about whether one of these is going to be the winner or not. So we're in a stage right where it's a race to see whose is going to be the best.

The Quantum Foundry is built around the idea that it's a fundamental research effort to try and develop materials that can host electronic states with protected quantum coherence. So if you look at the website of the Foundry there are three main research thrusts and each of these research thrusts are centered around trying to develop materials that have electronic states with protected quantum coherence. The idea is to develop materials that have protected qubit states. The manner in which they're protected varies depending on which thrust you're looking at. One process, which we call thrust one, which we call natively entangled materials and that is looking at materials that host an electronic state where just the symmetries of the material and the properties of the material itself protects the coherence of the quantum state you're trying to use for quantum information. That's one of the more exotic forms—the material itself is guaranteeing the coherence.

There's a second thrust where you try to realize a similar phenomena of protected quantum coherence, but what protects it is an interface between two different materials. So looking at the interfaces between some examples of superconductors and semiconductors. There's a large phase space that's really unexplored in terms of which materials are best to do that and how this can be achieved. So that's the second thrust and it's called interface topological states.

And the third thrust is based on the idea of finding a single electronic state that is highly coherent by itself because it's so isolated. An example here is people use special kinds of vacancy states in diamond. And then the idea is to develop a network in which you can interface that state with another state and make it a qubit via exchange of light or sound, for instance. To develop architectures of materials where quantum information can be protected by how you engineer the architecture and how you bring that information across networks is called coherent quantum interfaces. Those are the main three research thrust ideas and they're all built around developing separate tracks to see which states might be best for the next generation of quantum based electronics. The research thrusts encompass something like twenty-four total PIs, with twenty-one of the twenty-four are at UCSB. And there are three pillars for the vision of the Foundry in terms of the vision of the Foundry. The first pillar is of course this fundamental research effort.

The second pillar is interfacing with industry as you mentioned—having industry, interwoven within the center itself to help inform research directions to accelerate the development and eventual deployment of these materials into a device, that industry is going to then take over and and create. So the idea is that if you could involve industry at a very fundamental research level where we're looking at this really broad phase space—which direction should we go, which materials should we develop, which are the most promising—having industry as a voice in the room that can then say, "Hey look, from our experience this would be the most promising for eventual market potential." The idea is to try and bring them in at that level and involve them in the research.

And then the third pillar which is also somewhat coupled to industry is to develop what NSF calls the quantum workforce, it's going to be necessary to drive this coming age of quantum based electronics. I think there's consensus from industry and from a lot of academic institutions that the paradigm of quantum-based education should be updated beyond our traditional vision of it. Traditionally, if you take quantum mechanics in a physics class, you learn core theory and that's about it.

The idea is to have this quantum-based education, and to develop an interdisciplinary way of presenting it, which goes from the traditional theory instruction, to experimental touchstones, and also interdisciplinary approaches—having chemists, electrical engineers, and materials scientists involved. And also the content of how it touches real materials, to devices, to experimental simulations of quantum coherence, and so on. This is like a workforce pipeline where industry really needs people trained in all of these aspects. And so this is working to try and facilitate that and couple with industry.

Those are the three main tiers of the Foundry. There are [also] outreach efforts, we're partnering with the Center for California Science and Engineering Partnerships here on campus, we're partnering with community colleges, and also teachers and local community outreach events to try to address the mission for quantum-based education.

Xander: Fantastic! So, how do you think the Foundry's work is going to impact the world?

Prof. Wilson: We can make the Quantum Foundry at UCSB a nexus for innovation on the frontier of quantum based electronics and information—a major research hub, not just for research here at UCSB but also a larger network of both domestic and international collaborators that partner with the Foundry. We'd like to have it be this hub where a lot of innovation is discussed and ideas are put forward to accelerate the frontier of quantum electronics.

One interesting legacy is in this partnership with industry—we really are hoping it will succeed. It will hopefully serve for a model where we can have a kind of a more meaningful coupling between industry, research interests, and academic interests. There's this paradigm, this canonical timeline that people talk about: a new material—the time it takes to realize, to market is something like thirty years. If you're ever going to break that down you have to have industrial players in the room. We can learn a lot from industry and industry can learn a lot from us. And so trying to develop that relationship further in a meaningful way in the research frontier would be great. Finally, I think a big legacy will be this quantum-based graduate education. If we can start to accelerate this workforce pipeline problem, addressing that, that would be a major win for the national economy—we'll probably need it after this.

Xander: When do you think you'll be starting up the educational push towards more quantum? Do you think that's going to happen next fall? Or do you think it's going to be in a few years?

Prof. Wilson: We're ramping it up now. So the way the Foundry works is we have classes of graduate fellows that we admitted into the Foundry, roughly ten per year—our first class was admitted in January. The first courses which are targeted for this quantum-based education for this class of students starts in the fall. We'll be adding more classes and guiding more affiliate classes to align with a quantum-based track as the years go on. So that's a building process but it starts in the fall.

Xander: Okay, fantastic. So a big thing I've seen recently is that people are really interested in a useful quantum computer. Quantum computing seems like an awesome, possibly revolutionary thing, but it's hard for people to see how we can use it yet—especially people who aren't entrenched in the science of it. So do you see any useful applications of quantum computing developing soon and, if so, what are they?

Prof. Wilson: One thing I want to stress is that quantum-based electronics and using quantum information does extend beyond simple quantum computing. Quantum sensing has already been deployed, that's already a big thing. But quantum computing, I think there's a number of identified advantages for certain problems. Google has the recent demonstration of quantum supremacy for verifiable random number generation. That's already one demonstration of how quantum computing can be superior. Another idea is optimization problems. Quantum also holds an advantage there. A quantum computer...if I could just click my fingers in the air and make one happen that's what everybody would be wanting it for—you can dramatically speed up this optimization problem. That would be a major benefit.

There's a number of other proposed applications—people always talk about cryptography and potential things there but even for everyday life. One thing I do want to mention is that I've sat through some talks recently and it's interesting—it's not actually clear if people fully understand the total spectrum of applications where a quantum computer might be better. The idea for many people is currently to make some small scale quantum computers, and let people work on them and explore which applications there might have speed-ups for quantum computing versus classical computing. That's a vision that many companies and researchers are taking: let's just see what happens. There are not really that many stringent proofs for given applications about which is better—classical versus quantum. There are a few [applications] where it's clear one is better than the other, but a lot of it is just not known. From someone who's not a computing expert that's the impression I'm getting.

Xander: I really appreciate your perspective on it. It looks like we're all finished up, thank you so much for talking with me, this was great.

Prof. Wilson: Awesome. Alright, thanks a lot!

Xander: Thanks so much for talking with me! Have a good one.

Prof. Wilson: You too.