Alumnus Philip Johnson is an alum three times over and a physics jack-of-two trades! Check out how he got mixed up with the Dynamical Systems and Accelerator Theory (DSAT) and Superconducting Quantum Computing (SQC) groups below!

by Philip Johnson, Class of 1991, 1994 and 1999

What do quantum beams and quantum computers have in common? They are both examples of where the frontier of technology is entering the quantum domain. Of course, quantum physics plays a crucial role in modern technology (e.g. transistors, lasers); however, these present day technologies just scratch the surface of what may be possible in quantum mechanics. Particularly fascinating issues with both conceptual and practical significance include the following: How do we understand the appearance of a classical world from a quantum one; how do well-established classical disciplines fit into a deeper quantum description of nature; what is possible (technologically) in quantum physics?

As a postdoc with the Dynamical Systems and Accelerator Theory (DSAT) and Superconducting Quantum Computing (SQC) groups, I get to think about these issues every day. The diversity of projects with which I am involved is probably not the norm for a postdoc. This is challenging since, despite some common themes, in practice, I find myself working simultaneously on a number of different projects. The reward is that I am constantly learning new things, which is why I went into physics in the first place.

I began my physics career at Maryland as an undergraduate. I finished still wanting to know more, so naturally, I went to graduate school. Maryland was a great choice because it is strong in so many different areas, including cosmology and general relativity, which I hoped to study. It was also important to me to stay close to my family and friends in this area.

As a graduate student, I enjoyed working on different subjects. This has a downside because I definitely made slower progress by not focusing on just one project at a time. Despite being a theorist, I also had the unusual opportunity of teaching GradLab for a number of years, and I sometimes find...
myself regretting not becoming an experimentalist after my GradLab experiences. I have always enjoyed building things, or trying to fix them, and after a long day of calculating, I am sometimes especially tempted to trade my pencil for a soldering iron or volt-meter. My wife discovered this to her dismay a few weeks ago when I took apart my laptop while trying to fix it and found I wasn't sure how to get it back together again. Fortunately, it is working now even if it isn't looking very pretty.

Getting a postdoc here was serendipitous. My wife, Jennifer, and I did not want to leave the area, but if one wants to stay in academics, this is often not an option. Fortunately, while I was finishing my dissertation I learned that Profs. Bob Anderson, Chris Lobb, Fred Wellstood, and Alex Dragt were starting a collaboration on quantum computing. I had been interested in this area for the last few years, so I jumped at the chance to work with them.

Quantum computing has the goal of controlling the quantum world in a way that was never seriously entertained before. Indeed, it was not that long ago when computer scientists were speculating that the famous Heisenberg uncertainty principle (quantum uncertainty) fundamentally limits how small computers can ultimately be made before intrinsic randomness makes them useless. Surprisingly, the pioneers of quantum computing discovered that quantum uncertainty may not necessarily limit computation. Instead, it appears that quantum computers with powers dwarfing so-called classical computers may be possible, if only we achieve a sufficient understanding of quantum systems. What is more, the foundations underlying quantum computing have the potential to unify physics, information theory, and computer science in a profound way. The challenge is that the technology needed to build quantum computers goes far beyond anything we have achieved up to now.

One of the most exciting aspects of my work with the SQC group is that we are not only trying to understand quantum computers, we are trying to build one! What is more, because we are trying to engineer macroscopic quantum superconducting devices, the physics involved goes to some of the deepest questions in quantum mechanics. For example, one such question is how (and when) classical macroscopic properties emerge, and whether macroscopic quantum states can be produced (e.g., the infamous Schrodinger's cat).

In another direction, Prof. Alex Dragt and I are trying to better understand the quantum physics of motion. Prof. Dragt has been a leader in the classical
theory of nonlinear particle dynamics using sophisticated mathematics to model particle motion in accelerators. When one considers that billions of dollars are spent on machines that must accelerate particles that cover thousands of miles before colliding head on, one realizes that this field is also pushing against the state-of-the-art in technological control. Up to now, particle motion in these hugely complex devices has been modeled primarily with classical physics, which is a challenging enough problem since these nonlinear systems are subject to chaos. But ultimately, particle motion should be understood from quantum theory, and it turns out that there are many unanswered questions in this regard. Traditional quantum-mechanical scattering theory is great at predicting what happens when particles collide, but the questions that we are asking are of another type entirely.

Unexpectedly, there is a connection between these kinds of questions, and my thesis work with Professor Bei-Lok Hu. The subject of my dissertation concerned how particles move through space and time in quantum physics. The original motivation for this research direction is a surprising parallel between accelerated particle motion in quantum fields and black hole physics, and even quantum cosmology. What I didn't know when I was doing my graduate research was that there is a growing field of quantum beam physics that potentially ties this work to many other areas of exploration, including accelerator physics.

Another significant connection between quantum computers, quantum beams physics, and my thesis work arises from the process of decoherence. Decoherence is important in quantum cosmology where researchers have tried to understand how a classically behaving spacetime might emerge naturally from quantum gravity.

In my thesis work on particle motion, decoherence was important because the very idea of smooth, well-defined motion is classical, and so one must try to explain how this property emerges from the quantum theory of particles. In the study of decoherence, a set of particularly influential papers by Caldierra and Leggett applied methods similar to those I used in my thesis work to the analysis of superconducting interference devices (e.g. SQUIDS). Decoherence is now seen to be one of the fundamental obstacles to producing a quantum computer whose qbits are of any design (SQUIDS, Josephson junction, atoms, electrons, photons, molecules,…). Hence, this field is naturally multidisciplinary, and it gives me a chance to learn new science everyday.

One thing I do miss is teaching. Being a TA was a very rewarding part of my graduate career, and I hope that before long I will find myself in a position to teach again. What the future holds is uncertain, but I have at least achieved my first goal of finding fascinating and challenging work.