Spotlight

On Alumnus John Foster (Ph.D., 1973)

By: Karrie Sue Hawbaker, editor

Dr. John Foster never even took a physics class in high school. Now, he manages a $20 million radar system to study the physics of the ionosphere. Recently, I had the opportunity to catch up with him and find out about the journey in between.

It was a new Jesuit high school in Rochester, NY where John Foster spent his formative years. Four years of Latin and Greek as well as three years of Russian and French helped form the base of a broad educational experience. He had no exposure to physics and little to other sciences. However, the liberal arts focused curriculum was extremely strong, providing him with a wide knowledge base and key critical thinking skills.

Foster was very happy with the Jesuit style of education. He enjoyed it so much that he eagerly accepted a full tuition scholarship to Boston College, also a Jesuit institution. The scholarship was to study physics, a field that had captured his interest since the excitement of the space race had begun several years before. At Boston College, he reaped the advantages of a broad liberal arts college and of a quality physics program. He excelled academically, participating in the honors program, and enjoyed the bustling city of Boston. In 1967, he earned his Bachelor of Science degree and turned his eyes toward Maryland for graduate school.

Foster says he chose Maryland for a variety of reasons, but the first and foremost one was its proximity to NASA's Goddard Space Flight Center. The close Maryland-Goddard relationship paid off. His first year, Foster received a research assistantship that gave him the opportunity to work at Goddard. The downside of working off-campus his first year was that he didn't have the experience of sitting around in a teaching assistant office bouncing ideas off of each other or working through homework together. However, he says that the work was fascinating and the contacts he made at Goddard have been influential throughout the rest of his career. In fact, many of Foster's Goddard officemates and colleagues from his graduate years now hold prominent positions in space physics – in government laboratories and prestigious universities.

Dr. Theodore Rosenberg, who is now a research professor emeritus in the University of Maryland's Institute for Physical Science and Technology, served as Foster's advisor, guiding him toward a thesis on ionosphere-magnetosphere physics research. Foster speaks well of him as a mentor and says the two remain very close friends and

Spotlight

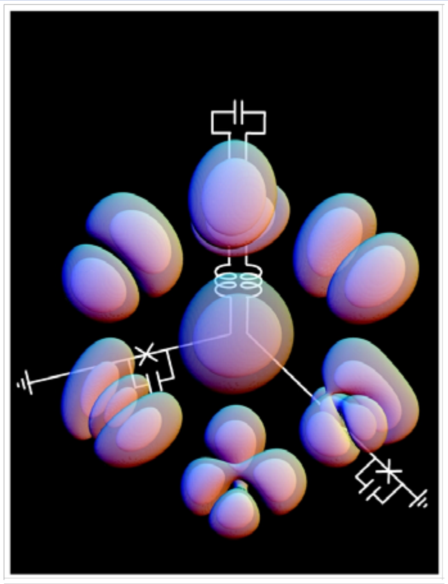
One Step Closer to a Quantum Computer

By: Huizhong Xu

For over twenty years, scientists around the world have been working toward the development of a quantum computer. That is, a computer that operates using quantum bits, giving it the capability to process information exponentially faster than the computers we have available today. Recently, my colleagues from the University of Maryland Center for Superconductivity Research and I have taken an important step on the road to this proposed quantum computer. We have seen the first evidence for entanglement of three macroscopic units in a superconducting circuit.

So, what is quantum computing?

Quantum computing is the proposed method of computation that would use collections of atoms, or other quantum systems, to process large amounts of information simultaneously. In the computers we have today, a bit (short for binary digit) is the smallest unit of data. It has a single value, either 0 or 1. A quantum bit, or qubit, which would be the smallest unit of data in a quantum computer, does not have a single value. It can be both 0 and 1 simultaneously. When qubits are entangled, each one can have not only its individual states, but also the possibility of shared states with every other qubit. For certain very difficult problems, a quantum computer can use these highly entangled states to achieve better performance than what conventional computers are capable to achieve. For example, in factoring large numbers, a quantum computer with only 1000 qubits could solve in minutes what today would take hundreds of conventional computers perhaps billions of years.



Macroscopic wavefunctions for a three-element superconducting circuit. The white axes represent the electrical circuit diagram of the three elements: the two Josephson junctions (x and y) and the LC circuit (z). The colored surfaces represent theoretical calculations of the wavefunctions of the lowest seven energy levels probed in the experiment.

What is entanglement?

Entanglement is an effect of quantum mechanics that “blurs” the distinction between individual particles in the sense that it is impossible to describe the particles separately no matter how far apart you physically move them. It is also the linked quality that allows for the qubits to process information so rapidly.

In May of 2003, my colleagues in the Center for Superconductivity were the first physicists to successfully create entanglement between two Josephson-junction phase qubits of macroscopic size. These findings indicated that Josephson-junctions - a type of electronic circuit capable of switching at very high speeds when operated at temperatures approaching absolute zero - could eventually be used to build an operational quantum computer.

What about the three-unit circuit?

Our latest work is the first to study the quantum mechanics of three macroscopic components: two Josephson junction qubits and a microcavity (a niobium inductor-capacitor (LC) circuit) connecting them. Each qubit is controllably coupled to the microcavity, providing a mechanism capable of transferring information between the qubits via the virtual qubit, the microcavity. We demonstrated this capability indirectly, by probing each qubit with microwave pulses. We observed spectroscopic evidence for the transfer of quantized oscillation of current from one qubit to the other, indicating the presence of entanglement between all three elements.

What is the next step?

The next step toward quantum computing, aspects of which University of Maryland researchers are now working on, will be to build an experiment that will allow us to actually transfer information from one qubit to another. Such an experiment may allow a direct observation of entanglement. The road to an operational quantum computer is not a short one, but physicists at the University of Maryland and around the world continue to work towards this scientific advancement that holds great promise for the world of science as well as the fields of electronics and technology.

Dr. Huizhong Xu earned his Ph.D. From the University of Maryland Department of Physics in 2004. Working with Professors Bob Anderson, Alex Dragt, Chris Lobb, and Fred Wellstood, he based his thesis upon the aforementioned research in quantum computing that he and his colleagues accomplished. Dr. Xu is currently a postdoctoral associate in the School of Applied & Engineering Physics at Cornell University. For more information about this research, “Spectroscopy of Three-Particle Entanglement in a Macroscopic Superconducting Circuit” by Huizhong Xu, Frederick W. Strauch, S. K. Dutta, Philip R. Johnson, R. C. Ramos, A. J. Berkley, H. Paik, J. R. Anderson, A. J.

*Dragt, C. J. Lobb, and F. C. Wellstood, Physical Review Letters, **94** 027003 (21 January 2005), see AIP Physics News Update 722, http://www.aip.org/pnu/2005/split/722-2.html . Dr. Xu can also be reached at hx34@cornell.edu.*

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colleagues. He is also thankful for Rosenberg's willingness to introduce him to so many people at such a young age. Since the space physics program at Maryland was young and small in those days, Foster supplemented his graduate education with a significant number of classes in the field of solid state physics. Solid state research was (and is) such a rapidly changing field; therefore, most of what he learned was outdated by the time he earned his Ph.D. However, he found the work – and working with Dr. Arnold Glick, now professor emeritus in the Department of Physics – a very positive experience. Specifically, he feels that he learned how to learn something, an extremely valuable skill for any scientist.

Foster says that, overall, he found the Maryland experience very positive. It was difficult, much more rigorous than anything he'd done before. But, it was exciting at the same time and it was all worth it when he received his Ph.D. in 1973.

For the first year and a half after graduation, Foster continued to work with Dr. Rosenberg, this time as a post-doctoral associate. At the time, Rosenberg was working with balloon x-ray programs in Antarctica. The experiments gave Foster the opportunity to travel there twice, flying balloons into the stratosphere to study the plasma physics interactions from the x-rays that result from the radiation emitted from high energy particles coming out of the magnetosphere.

Then, around the time Foster had decided it was about time to leave the proverbial nest of the University of Maryland, he attended a space physics conference in Coolfont, West Virginia. He took his relatively new bride with him and she managed to find him a job. She met a group of people from Canada over dinner one night and soon he found himself working with the Canadian National Research Council. It was this position that moved his career focus from the magnetosphere to the ionosphere. He became involved in using satellites to study the ionosphere through his work with the International Satellite for Ionospheric Studies (ISIS), a joint Canada/United States program to determine how the ionosphere reacts to changes in the sun's radiation and a program that Foster found enlightening.

ISIS held semi-annual meetings in either the United States or Canada and it was at one of those meetings that Foster met a physicist by the name of Dr. Peter Banks, who demonstrated an interest in the work Foster and his team were doing. Not long after that, Dr. Banks went to Utah State University to serve as their physics department chairperson. He made several new hires in this capacity, including John Foster as a research faculty member.

Foster gained extensive experience in this position. In addition to taking on new and interesting topics in his area of research, he had the opportunity to teach a few classes, to learn how faculties work and to seek out funding himself. He says he also began to see the value in having a critical mass working on a research project.

Foster had made several contacts by this point, many thanks to Dr. Banks, one of which was Dr. John Evans (who is considered by many to be the founding father of radar space physics). He was at the Massachusetts Institute of Technology's Haystack Observatory when he was considering a new career opportunity. And he called John Foster to take over his group. Foster leapt at the opportunity.

The Haystack Observatory is located about 50 miles outside of MIT's main campus in Boston. The location is excellent for radar space research, which requires a large amount of land to isolate the high-power transmitters from the neighbors. It's also easy on the eyes, especially during this time of year when the view from Foster's office window is a landscape of snow-covered forests.

There, Foster manages a $20 million radar system, leads a productive group of about 15 people and serves as the observatory's associate director. The system studies almost all of the characteristics of the ionosphere – like the plasma density of electrons and ions, ionosphere temperatures, Doppler velocities and ion composition.

This data allows Foster's team to draw conclusions, including characterizations of the climate of the ionosphere and of space weather. And combining the results of his work with other techniques, including satellite imagery and global positioning systems, scientists can gain a rather comprehensive understanding of the ionosphere. Since the middle latitudes (like those through Massachusetts) produce a lot of data that the satellite system can detect, Foster has no trouble keeping busy. And he's pleased to say he's been able to see progress over the years. He and his colleagues began looking rather locally, but now they are beginning to see the overall system of the atmosphere and how it works together. Foster attributes much of this to the increase in collaboration among physicists and with other disciplines.

When asked about advice to current students or recent grads, Foster stresses the importance of contacts. He encourages young physicists to, in addition to studying hard, take the time to make contact with the other professors, post-docs, students and collaborators around you. He also encourages advisors to aid students in making these connections – much like Dr. Rosenberg did for him so many years ago. He says that you do not know what your future holds and you'll never know with whom you'll cross paths again. So, he recommends keeping positive relationships and avoiding burning any bridges.

Foster also wishes to pass on some words of wisdom that were given to him by one of the members of his thesis committee. When he finished defending his dissertation, this gentleman told him that earning a Ph.D. in physics means more than the fact that you've done something. It also means that you are capable of doing something else. You have received training in how to go about doing something. And that is a skill that is more valuable than you are likely to ever fully realize.

If you have questions or comments for Dr. Foster, please contact the editor. She will be happy to pass along the message.

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