# Interview with Don Eigler: What's wireless and miniscule?

## IBM physics researcher Don Eigler looks 15 years into the future of wireless technology

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It seems that every generation of new wireless technology is smaller than the last. At IBM's Almaden Research Center, IBM Fellow Don Eigler and his research group are reaching whole new frontiers of miniaturization, building molecule-sized logic gates, one atom at a time. Ira Kalb talked to Don to learn what today's developers can do to prepare for the future of wireless.

All wireless developers have a dilemma: they have to develop products for the near term while thinking about what is likely to happen in the future. To make things more complicated, the industry's ground keeps shifting, with standards not yet firmly established. GSM, PCS, WAP, EDGE, GPRS, UMTS, 3G, Bluetooth, i-mode, and many other standards, protocols, and technologies are either implemented or being developed; industry observers see many of these as bridging technologies that will not last very long. It seems that as soon as one standard emerges, somebody else comes along with another one or a modification that can throw big curves in the plans of wireless developers.

Futurists predict the eventual emergence of a ubiquitous TCP/IP network, over which users will be able to communicate using their wireless PCs, cell phones, watches, and other wearable or implantable devices. Such networks will also link users with appliances, transportation systems, Global Positioning Systems, medical monitoring systems, and a myriad of other useful machines and systems.

In order to get a look into the future, I recently interviewed Donald Eigler, an IBM Fellow who works at the IBM Almaden Research Center in San Jose, California. This lab is one of eight IBM research division locations, and is dedicated to scientific and technical basic and applied research that creates and brings new technologies rapidly to market. The focus at Almaden is on information research in areas such as data storage, database management, and physical phenomena that serve as a foundation for IBM's basic technologies. Don works on technologies and projects that may have application 15 years in the future -- specifically, the physics of nanometer-scale structures. He

joined the lab 16 years ago with a BA and a PhD in physics from UC San Diego, and post-doctorate work at Bell Labs.

## Meet Don

Don greeted me in the lobby of the Almaden Research Center, accompanied by his two very large dogs, Argon and Neon. They're not just pets, by the way -- he's training them to be service dogs that will provide assistance to people with disabilities.

**Figure 1. Don Eigler and a friend**

**developerWorks:** What got you interested in working on technologies that are years away from everyday use?

**Don Eigler:** That is what most physicists do if they are not doing directly applied work. A ten-year time horizon from discovery to marketplace is considered a short time in physics. There are two main motivations for our research: one, laying the foundation of scientific knowledge that will be important for the future of IT; and two, keeping our eyes open for discoveries that will advance existing technologies, or create new ones.

**dW:** What did you do to prepare yourself for your current work?

**Eigler:** In addition to my studies in school and at Bell Labs, my father had a strong influence on me. He could do a lot of different things and was able to design and build things that worked. At home, he was always working on projects, and impressed upon all of his children that if you need to accomplish something, you just figure it out and go do it. That is an important skill for someone who does the pioneering physics that we do here in the lab.

**dW:** How long have you been in your current position?

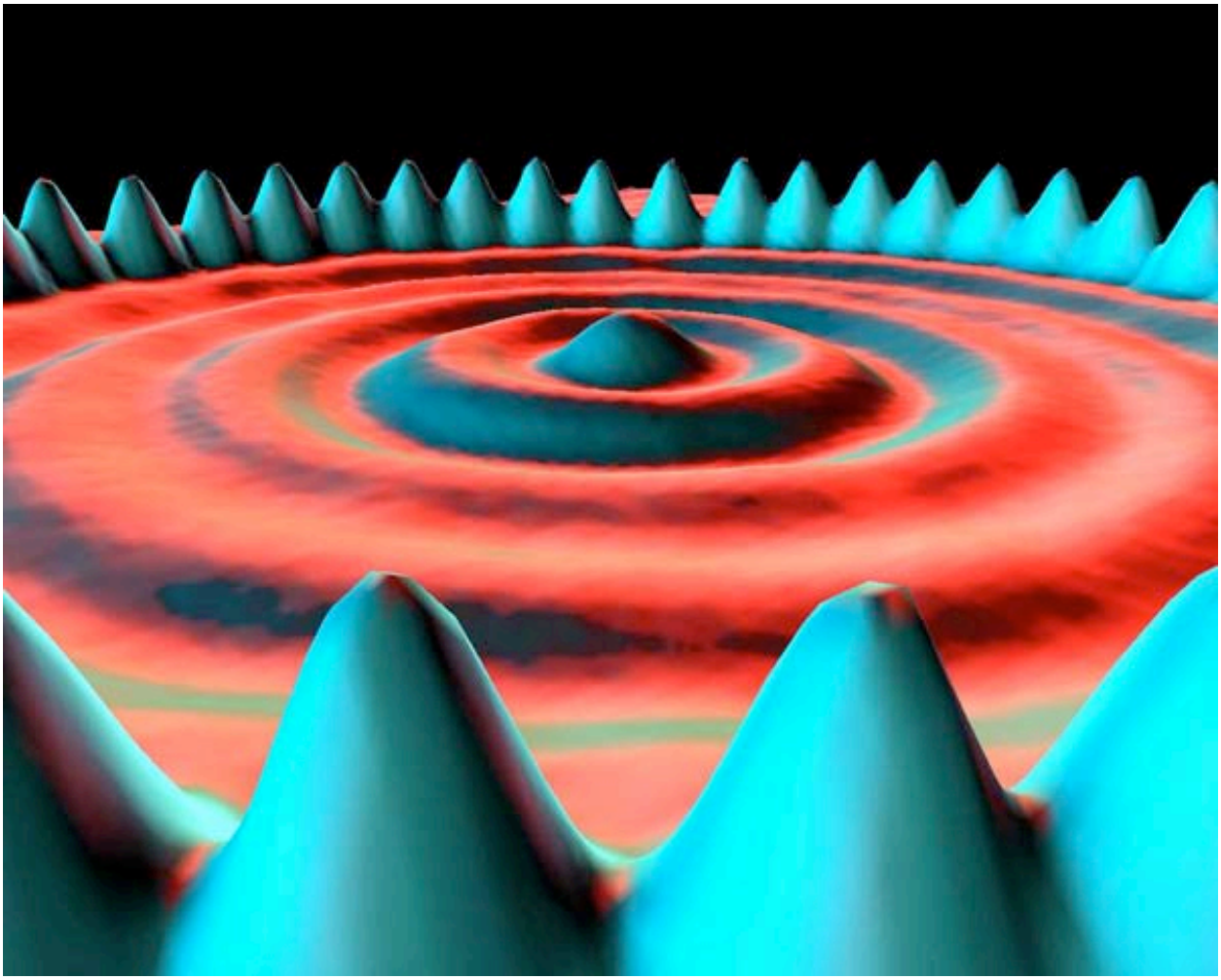
**Eigler:** In 1993, I became an IBM Fellow. IBM Fellows are technical professionals who have been recognized for achievements that have changed our industry. Fellows are also given ongoing support by IBM to facilitate future accomplishments. There are 40 or so Fellows at IBM; it is a great personal honor to be counted among them. Being a Fellow provides me with substantial freedom to do what is important.

# Working from atoms

**dW:** So, what is important? Specifically, what does your group do?

**Eigler:** My group's specialty is low-temperature scanning tunneling microscopy. We use these microscopes to build our knowledge of the physics of small structures. We consider small structures to be those made up of a handful of atoms, or perhaps a little larger. (See them in microscopic view in Figure 2.) The future of our industry is in mastering small structures and making them useful for computation and information storage and handling.

**Figure 2. A corral of iron atoms. This image was produced by the scanning tunneling microscope used by Eigler's research group.**



**dW:** What is your role within the group?

**Eigler:** I am the nominal leader/manager of a small team -- five people, myself included. We each bring to the lab our unique personal strengths. I do most of the blabbing.

**Figure 3. Eigler's group's scanning tunneling microscope**

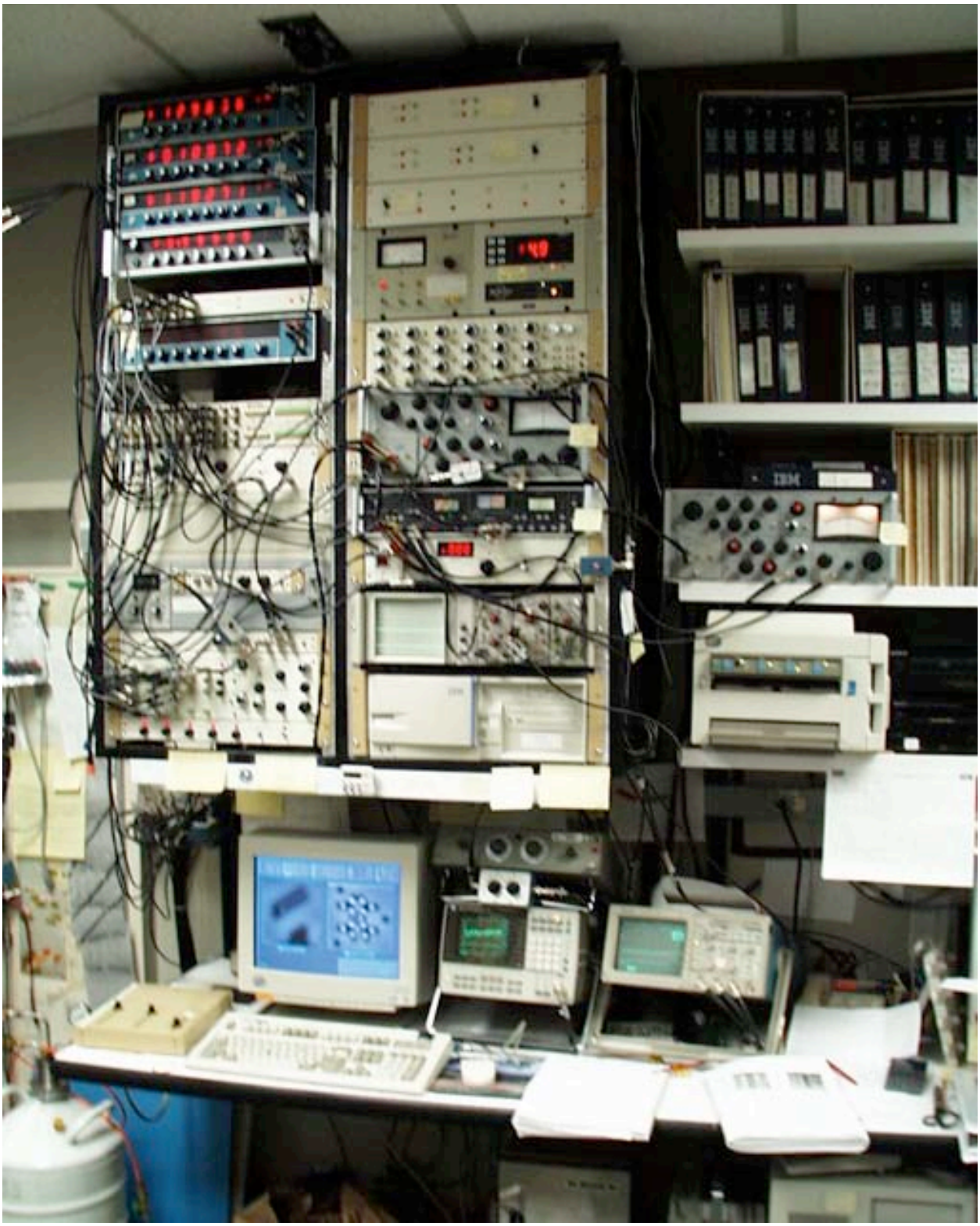
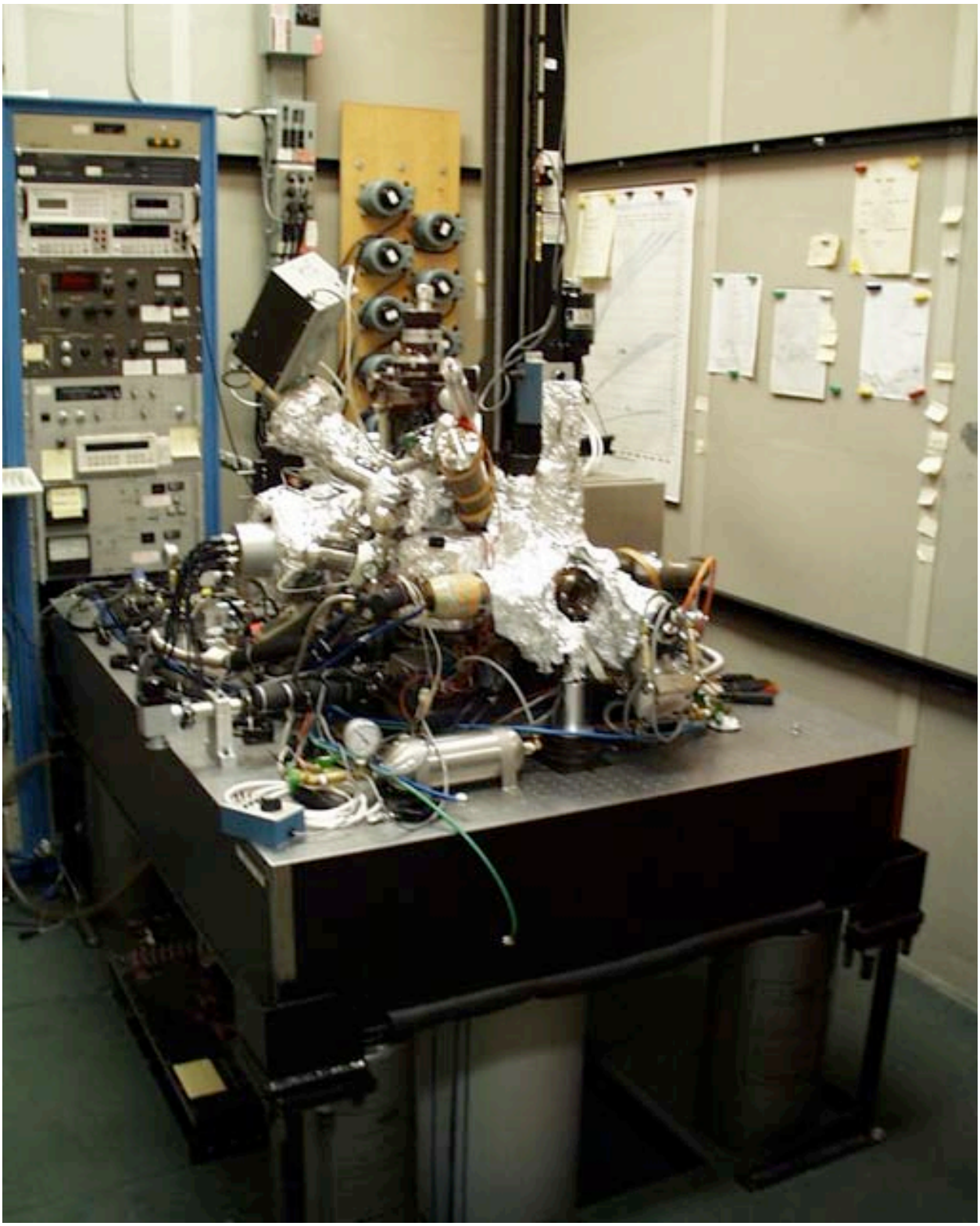


**Figure 4. Another view of the microscope**



**dW:** How long have you been doing this?

**Eigler:** I started with a lab of my own in 1986. Others joined starting in 1988. Our team was built from postdocs, engineers, and scientists.

**dW:** I guess your work in moving atoms from place to place at will is the beginning of atomic-sized memory and computing devices. In your view, is this research the first step towards very powerful wireless wristwatch computers, and wireless pill-sized machines that can communicate and repair damage inside human bodies?

**Eigler:** Our hope is that the work we are doing will benefit any field that can benefit from the control of matter at an atomic scale (one-fifth of a nanometer in diameter). Our work has the potential to be applicable to a wide variety of technologies. We are creating the pathway to incredibly small computers and devices that help people in a variety of ways. This has the potential to profoundly impact wireless technologies by driving electronics forward. It will enable new technologies that we can't yet imagine.

## Applying research today and tomorrow

**dW:** What are some of the ways in which we're benefitting from your research into technologies that are perhaps 15 years away from daily use?

**Eigler:** There has been no obvious direct impact on existing technologies. We are really working at the bleeding edge of technology. It has affected IBM's outlook on the future. It has gotten people very excited, and has had substantial PR value. For me, it is very important that we have an immediate, short-term impact in these areas as we continue to work on our future.

**dW:** How can wireless developers benefit from your research today?

**Eigler:** They are probably not thinking 15 years in the future. We will be able to extend our technologies to very small dimensions so they [developers] can be developing very small, low-power wireless devices -- and software for controlling them. We are making sure that there is a very healthy future for wireless. Today, IBM is making silicon-germanium devices, enabling development of much faster electronics for wireless mechanisms. The research on these devices was done years ago.

**dW:** What can, or should, wireless developers be doing now to plan for the future?

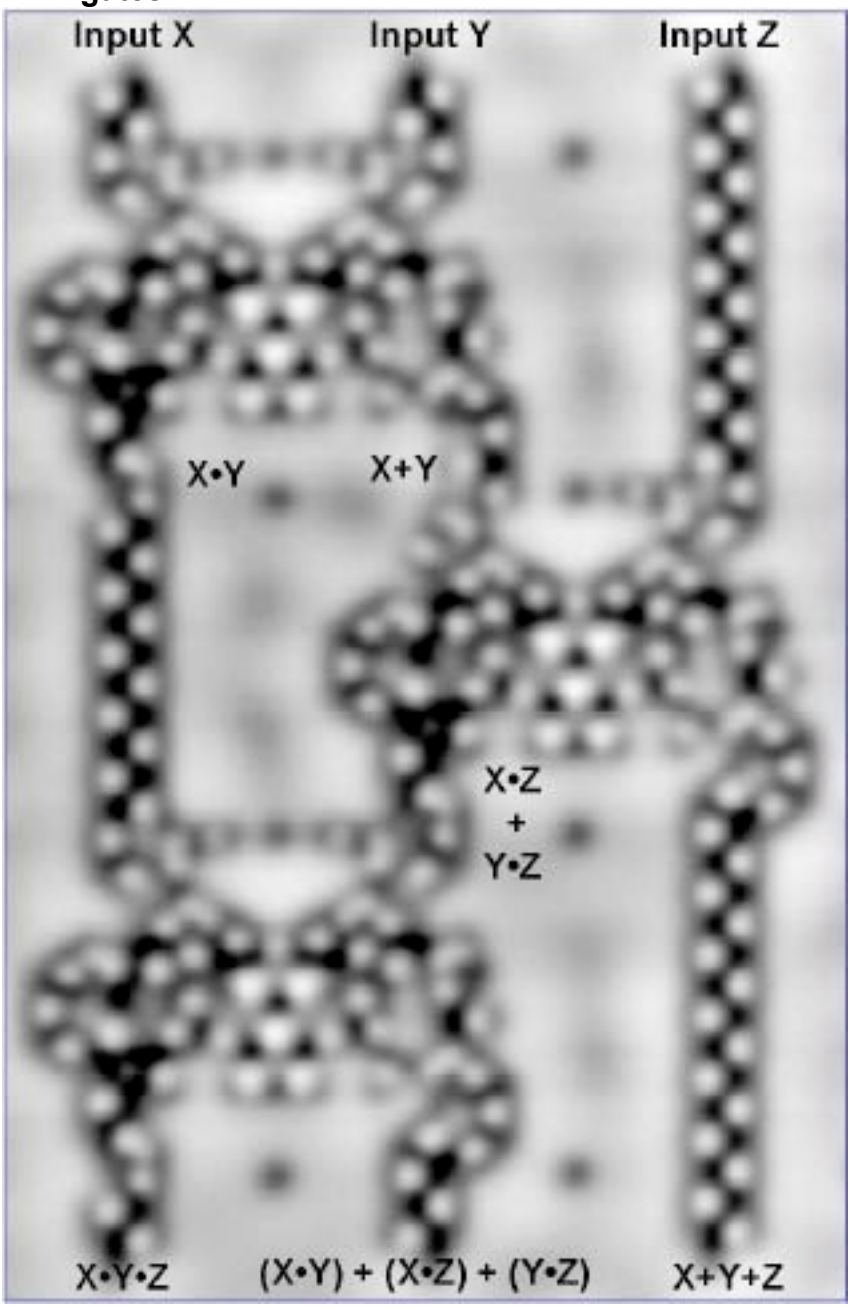
**Eigler:** They can begin thinking about what they could develop if they had 100 to 1,000 times the capability they have now. They can push the envelope.

**dW:** What wireless development will take place in the future based on the work you are doing today?

**Eigler:** It could be radically different in the future. I wish I had an intelligent personal assistant that would do things for me. In the '50s and '60s, we had very talented

secretaries who would do things for us. Now we don't have that. I can envision a wireless implantable device that would be a super-secretary and do all the things I need done for me. This device would learn from experience and context, and free us from doing all of the administrative, repetitive, and annoying things that we have to do, such as make travel arrangements. The atomic-sized circuits we just laid out in the lab are 260,000 times more dense than state-of the-art CMOS technology (see Figure 5). Potentially, this means that wireless developers can have 260,000 times the computing power in the same size chip they use today.

**Figure 5. CO molecules on a copper surface that have created logical OR and AND gates**



**dW:** How do you use wireless technology in your work?

**Eigler:** My laptop can communicate anywhere at work or at home. This changes the way I use my laptop.

**dW:** Do you see any breakthroughs in wireless technology as a result of your work?

**Eigler:** I see how my work plays into building a higher dependence on wireless technology in the future. One of the applications of extremely small circuitry is that it will dramatically increase the capability of wireless devices.

**dW:** What do you think the wireless world will look like in 2017?

**Eigler:** I can see having a watch that functions as a personal assistant. I can see very small implantable devices with a variety of different medical applications. I see augmenting human capability with implantable and wearable devices, powered by the body's metabolism. Small structures will play a huge role in delivering greater functionality and fewer complications from implantable and wearable devices.

# A tour through the future

After we spoke, Don gave me a tour of his lab and a demonstration of the microscope his group has built, as well as the one they are currently building (shown in Figures 3 and 4). What he showed me, in real time, is one of the most interesting and exciting things I have ever witnessed. We looked at individual molecules, atoms, and electrons with the aid of his low temperature scanning tunneling microscope. He showed me how he could move atoms and cause a controlled chain reaction that performed logical operations on data (shown in Figure 5). For more information on this work, check out the paper by Eigler's group, *Molecule Cascades* (a link is provided in the Resources section below).

It was more than exciting to get a glimpse into the future, where we will be using wireless devices that extend our capabilities -- improving our ability to communicate, protecting us from danger, helping us to solve medical problems, freeing us from drudge work to let us focus on more interesting things, and enabling us to continue creating new and better devices with fewer of the encumbrances we accept today.

After witnessing the destructive forces of 9/11 and living with all the bad news of the past year, it was uplifting to see the exciting research on the frontiers of scientific discovery being done in Donald Eigler's lab. It is hard to know what the wireless world will look like in 2017, but after my visit with Don, I am more optimistic about it than ever before.

# Resources

* Check out "Molecule Cascades," by A.J. Heinrich, C.P. Lutz, J.A. Gupta, and D.M. Eigler (*Science Express,* October 2002) to learn about the details of Eigler's group's research. (Warning: this document is quite technical and not for the faint of heart!)

* Read the release on Quantum Mirage, Eigler's group's nanotech communications research.

* "Meanwhile, Back at the Corral," by Bruce Schechter (Think Research), has more information on this topic.

* Here you'll find Don Eigler's research biography.

* This site at Almaden Research Labs contains more interesting molecular visualization images similar to the shown in Figure 2 in this article.

## About the author

Ira Kalb is a consultant, author, part-time professor, and president of Kalb and Associates, an international consulting and training firm. He is also an artist and a woodwind musician who served on the board of directors of the Jazz Bakery -- a nonprofit corporation showcasing world-class musical talent in a world-renowned venue. Contact Ira at irakalb@KalbAssociates.com.