A Giant Step toward Infinitesimal Machinery

November 6 2007

What are the ultimate limits to miniaturization? How small can machinery--with internal workings that move, turn, and vibrate--be produced? What is the smallest scale on which computers can be built?

With uncanny and characteristic insight, these are questions that the legendary Caltech physicist Richard Feynman asked himself in the period leading up to a famous 1959 lecture, the first on a topic now called nanotechnology. In a newly announced global Alliance for Nanosystems VLSI (very-large-scale integration), researchers at Caltech's Kavli Nanoscience Institute (KNI) in Pasadena, California, and at the Laboratoire d'Electronique et de Technologie de l'Information-Micro- and Nano-Technologies (CEA/LETI-MINATEC) in Grenoble, France, are working together to take the pursuit of this vision to an entirely new level.

For about three decades after Feynman's lecture, scientists paid little heed to what was apparently viewed as his fanciful dreams in this regard. But more recently, particularly in the past two decades, the field of nanotechnology has been solidly established. Underlying this is an immense amount of careful research, carried out in laboratories worldwide-work that has been realized one advance at a time.

To date, almost all of these pioneering investigations have focused upon solitary components and individual physical effects at the nanoscale. (One nanometer is a billionth of a meter, about ten times the size of a hydrogen atom and a million times smaller than the period at the end of this sentence.) These components hold great promise as the fundamental building blocks of complex future nanosystems, that is, as the ultraminiature machines and computers of Feynman's dreams. But, so far, very little work has actually been carried out to assemble these individual elements into complex architectures.

The Alliance for Nanosystems VLSI (NanoVLSI) is an unprecedented partnership founded to break this impasse. It is an international collaboration between researchers in nanoscience at Caltech and in microsystems science and engineering at CEA/LETI-MINATEC, one of the world's premier, state-of-the-art microelectronics research foundries.

Michael Roukes, professor of physics, applied physics, and bioengineering at Caltech, who was the founding director of Caltech's KNI, has spearheaded the initiative from the academic side. "There is a lot of hype about 'nano' being the solution to many different problems," says Roukes. "It's time for us to start delivering, but to do that we have to think about how to assemble and produce complex systems containing thousands of devices all singing in harmony."

Why complex systems? Huge programs, with millions of lines of code, make up the operating software for today's laptop computers. These must run on microelectronic chips that now integrate several hundred million transistors to achieve their immense computational power. Nanotechnology has the potential of carrying this kind of complexity into entirely new realms, going beyond electronic computation to include capabilities, for example, for detection of very small amounts of chemical and biological molecules, or for measurements on individual living cells within complex microfluidic systems, to name just a few. The first generation of these new chemical processors-on-a-chip is still quite simple compared to their ultimate potential. But already they are spawning new tools for research in the life sciences and medicine and new applications in clinical diagnosis.

A systems approach to nanotechnology is required to ramp up the complexity of these systems-on-a-chip. But achieving this requires access to the kind of multibillion-dollar fabrication capabilities used to build today's microprocessor chips. In such environments, standardized processes are the rule without exception. Experimentation with unconventional materials and techniques is strenuously avoided, since cutting-edge processes are highly susceptible to contamination. Extremely high quality at these foundries must be preserved to maintain production yield. But innovation must occur somewhere. For three decades, CEA/LETI-MINATEC has been fulfilling a critical role, pioneering the introduction of novel processes into state-of-the-art protocols used to produce VLSI microelectronic systems en masse. Within this new alliance, CEA/LETI-MINATEC researchers are now turning their attention to new challenges at the nanoscale. "The Alliance for Nanosystems VLSI is a perfect illustration of the potential for innovation generated by the meeting of science and technology," says Dr. Laurent Malier, the director of CEA/LETI-MINATEC. "I am excited to see Caltech and CEA/LETI-MINATEC share this ambition."

Those today who are working to advance nanoscale research and technology still find much inspiration in Feynman's early insights. He saw no fundamental reasons barring the assembly of machines and computers down to the smallest possible dimensions, namely, that of nature's basic building blocks-atoms and molecules. Step-by-step, with the help of partnerships like NanoVLSI, nanotechnology is approaching this dream.

For more information about the Alliance for Nanosystems VLSI, visit www.nanovlsi.org

Source: Caltech