Penn Theorists to Create Optical Circuit Elements

September 27 2005

Engineers at the University of Pennsylvania have theorized a means of shrinking electronics so they could be run using light instead of electricity. In the search to create faster, smaller and more energy-efficient electronics, researchers have looked elsewhere in the electromagnetic spectrum, which ranges from the low-frequency energy used in everyday electronics to the high-frequency energy of gamma rays, to pass the limits of conventional technology.

In the Aug. 26 issue of Physical Review Letters, currently online, the Penn theorists outline how familiar circuit elements -- inductors, capacitors and resistors could be created on the nanoscale (about a billionth of a meter) in order to operate using infrared or visible light. The Penn researchers describe how nanoscale particles of certain materials, depending on their unique optical properties, could work as circuit elements. For example, nanoscale particles of certain metals, such as gold or silver, could perform the same function in manipulating an "electric" current as an inductor does on a circuit board.

Optical electronics would make it possible to create faster computer processors, construct nanoscale antennas or build more information-dense data- storage devices. Optical electronics could also have exotic applications that simply are not possible with conventional electronics, such as the ability to couple an electronic signal to an individual molecule or the creation of biological circuits.

"The wavelength of light can be measured in hundreds of nanometers and the technology is now available to create structures that would operate on the same or smaller scale as the wavelength of light," wrote Nader Engheta, lead author, and H. Nedwill Ramsey, professor in the Department of Electrical and Systems Engineering of Penn's School of Engineering and Applied Science. "Our work is theoretical, of course, but we do not foresee any sizable barriers to our plan to make these circuit elements in the near future."

Before they could describe how to create optical circuit elements, Engheta, his coauthors and students Alessandro Salandrino and Andrea Al had to first envision how nanoscale materials might interact with light. To do so they looked at a property critical to basic wave interaction called permittivity, which describes how a particular substance affects electromagnetic fields. If a small sphere is created, about a few tens of nanometers across, they explained, light would affect it differently based on its permittivity.

According to their models, the theorists demonstrated that nano-sized sphere made up of a nonmetallic material such as glass with permittivity greater than zero would act like a miniaturized capacitor. A nano-sized sphere made up of a metallic material such as gold or silver with a permittivity less than zero would act like a miniaturized inductor. Either material could also function like a miniaturized resistor, depending on how the optical energy is lost in it.

"So now we have three basic elements of a circuit," Enghata said. "Stacked one upon the other, you could create fairly advanced combinations of circuitry. It is even possible to use these elements to create 'nano' transmission lines and 'nano' cables.

"For years, conventional circuit elements have been the basic building bloc in making functional circuits at lower frequencies," Engheta said. "But now we have the tools to push back the limits of speed and power on electronics. This technology could have innumerable applications for consumer products, advanced instrumentation and even medicine."

Source: University of Pennsylvania