Opto-chips shatter records for bandwidth and low voltage

A new type of organic molecule that promises to revolutionize telecommunications and other optical and electronic functions has been developed by researchers at the University of Washington in Seattle and the University of Southern California in Los Angeles.

When the molecules are embedded in a polymer, the combination forms a polymeric electro-optic device. Larry Dalton, a chemistry professor at the University of Washington, who heads the project, told *IEEE Spectrum* that the new materials have the potential to be used for satellite and optical-fiber telecommunications circuitry, phased-array radar, optical gyroscopes, and analog-to-digital converters—all with very low drive voltages and high bandwidths.

Most recently, the researchers built an electro-optic modulator with a bandwidth above 110 GHz and a drive voltage below 0.8 V, a feat never before accomplished with any other material. Although other modulators have operated with bandwidths above 100 GHz, their RF drive voltages have remained high (about 5 V), according to a report published by the researchers in a recent issue of *Science*.

The new molecules belong to a larger class of molecules called chromophores, whose indexes of refraction change when they become polarized in an electric field. With the molecules embedded in the polymer, which acts as a support matrix, the application of appropriate voltage gradients will steer or modulate light passing through the polymer.

"Once you have a voltage-controlled index of refraction, you can manipulate light in the material at will," said Dalton. "You can steer it, you can split it into two beams, apply voltage to one arm, and create destructive interference at the output. That translates into the introduction of an electrical signal onto an optical transmission as an amplitude modulation."

Unfortunately, embedding the molecules in the polymer in such a way as to exploit their optical properties has been tough. The difficulty arises from electrostatic interactions between the chromophores that tend to align them symmetrically about a center point—a configuration that drastically degrades the overall polarization of the structure. For the best performance, said Dalton, they should all line up in the same direction.

Through theoretical studies, Dalton and his colleagues discovered that if the chromophores, which normally have an elliptical shape, could be given a more spherical shape, the electrostatic forces between them would be much smaller, allowing them to become aligned in a more effective way.

So the researchers synthesized chromophores that were fatter in the middle. As a result, the electro-optic properties of modulators built from these chromophores were much improved. The voltages needed to drive them dropped from a typical value of 6 V down to less than 1 V. This is important, said Dalton, because "the fastest electronic families don't put out 6 V, they put out less than a volt." With their low drive voltage requirement, the devices do not need a low-noise amplifier, which would erode the extremely large bandwidths of the material and the devices made from it.

"The intrinsic bandwidth of the electro-optic material is 365 GHz, measured by pulse techniques," said Dalton. That far exceeds the bandwidth of any other type of material. Devices built with the new chromophores have bandwidths up to 113 GHz. Bandwidths on the order of 100 GHz are needed for high-speed communication, for example, between two processors in a supercomputer.

Another important plus is the fact that the new material can be integrated into 3–D arrays built directly on top of conventional ICs, using standard masking and reactive ion etching techniques. So densely can the electro-optic devices be integrated that the interconnections between the circuits supplying the voltage to the electro-optic elements can be really short.

Dalton sees endless possibilities for such highly integrated devices—for example, compact anti-collision radar for cars or very efficient phased-array radar systems for satellites or planes. He also expects to see commercialization of the devices in the near future, driven by the prospect of doing things impossible to do with other technologies.

LINDA GEPPERT, *Editor*