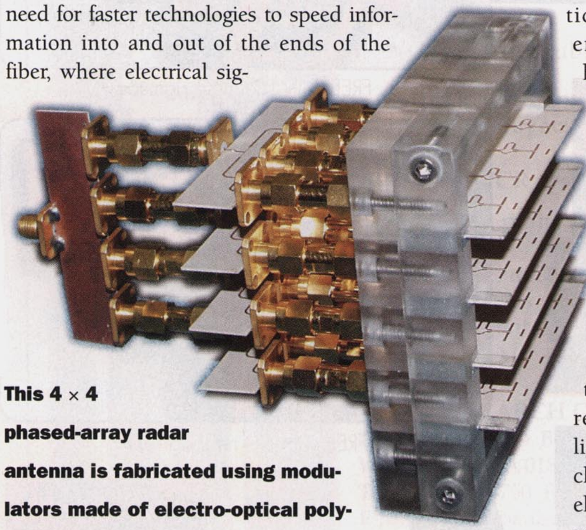
Polymers Speed Electro-Optical Conversion

As the capacity of optical fibers to carry information increases, so does the need for faster technologies to speed information into and out of the ends of the fiber, where electrical signals are transformed into optical ones and back again. Now researchers from the University of Southern California and the University of Washington have found a way to make this transformation faster and more energy-efficient, using polymers containing organic chromophores. They achieved modulation with a potential of less than 1 V and have evidence that switching speeds as high as 100 GHz are within reach.



This 4 × 4 phased-array radar antenna is fabricated using modulators made of electro-optical polymers embedded with specially shaped chromophores, which allow higher speeds and require lower voltages.

Currently, lithium niobate is used for electronic modulation, but the material has several limitations. Most important, lithium niobate requires a 5-V drive potential to adequately change its optical properties and, thus, to modulate a laser signal. This means increased energy requirements. It also means that the voltage is too high for use on current microchips, which prevents the use of optical fiber connections in and between such chips. Moreover, the switching rates of lithium niobate have not exceeded 70 GHz, which is too slow for near-future needs.

To overcome these limitations, researchers have long sought to develop electro-optical polymers that have higher speeds and require lower voltages. In particular, chromophores embedded in polymers have been a focus of research, because these molecules (which give rise to color in many substances) become a polarizing medium when an electric field is applied. The presence or absence of the polarization of the laser beam can then be used to carry a signal. At the receiving end, polarized light passing through the chromophores induces an electric field, thereby converting the optical signal back into electricity.

The problem is that the chromophores tend to line up in a way that interferes with their polarization. Each chromophore, which is naturally ellipsoidal, has a positive and negative end, and the molecules tend to align with pairs of chromophores facing in opposite directions. This phenomenon dilutes the polarizing effect of any applied field.

"Our solution was to reshape the chromophores to make them more spherical and less ellipsoidal," explains Bruce Robbins, a team member at the University of Washington. "That way, the chromophores no longer tended to align opposite to each other, and so when the field was applied, they were free to align with it, producing the polarizing medium." The researchers changed the molecular shape by adding more bulky hydrocarbon chains.

Using the special chromophores, the scientists demonstrated optical modulation at low frequency with an imposed voltage of only 0.8 V (*Science* **2000**, *288*, 119). Generally, at frequencies above 40 GHz, voltages are twice as high as at lower frequencies. This would still allow operation at low enough voltages for integration on microchips and, thus, could open bottlenecks in computer communication speed that are becoming increasingly important as transistor speeds continue to rise. Researchers will soon test this possibility by running the new chromophore-containing polymers at the 100-GHz frequencies that some other experiments have shown should be feasible. Ω