Rotund Molecules Key To High-Speed Telecommunications

A new family of electro-optic chromophores—conjugated organic molecules that excel in using an electric field to manipulate light—is pointing the way to a revolution in telecommunications and information processing.

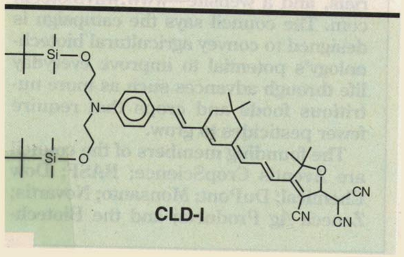
One of the key figures in that revolution is Larry R. Dalton, a professor of chemistry at the University of Southern California (USC) and the University of Washington, Seattle. Last week, Dalton and his colleagues reported that they have embedded one such molecule, code-named CLD-1, in a polymer matrix to make an electro-optic device with dramatically improved performance. The device can operate on less than 1 V and is capable of encoding information from electrical signals onto optical transmissions at the rate of more than 110 gigahertz—the equivalent of 110 billion bytes per second [*Science,* **288,** 119 (2000)].

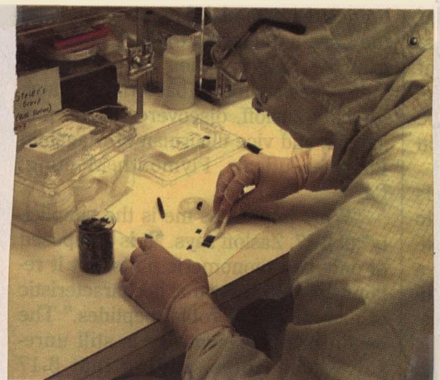
Although data rates this high had been achieved in earlier polymer electro-optic modulators in the lab, the drive voltage had remained relatively lofty—around 5 V. So a high-speed device that could operate on less than 1 V has been sought because it would markedly improve the efficiency of fiber-optic (and satellite) communication systems.

The device reported by Dalton and his colleagues, including University of Washington chemistry professor Bruce H. Robinson and USC electrical engineering professor William H. Steier, could eliminate lengthy download time on the Internet resulting from the bottleneck caused when transferring digital data onto fiber-optic transmission lines.

James G. Grote, an electrical engineer at the Air Force Research Laboratory at Wright-Patterson Air Force Base near Dayton, Ohio, terms the work of Dalton and coworkers "a milestone. No one else in the world has come close" to what they have achieved. Grote believes that in certain high-speed applications such organic materials will replace the lithium niobate ($LiNbO_3$) crystals currently used in electro-optic modulators.

Polymer modulators also will usher in new applications made possible not only by their greater speed and lower voltage but also by their significantly smaller size, weight, and price tag, Grote points out. Dalton says a new generation of radar—indeed, "instantaneous 360° radar"—could emerge, not only for aircraft navigation but also for collision avoidance in cars. And the polymer modulators also would allow direct integration with semi-





Researcher works with polymeric electro-optic chips in a clean room.

conductor electronics, producing compact, highly sophisticated opto-chips for increasingly powerful computers.

Researchers pursuing such dreams have been trying for more than a decade to harness the unusual properties of electro-optically active materials in modulators (C&EN, March 4, 1996, page 22). Because an applied voltage causes a change in the material's refractive index, light can be switched from one path to another. The same phenomenon allows a modulator to encode information onto laser beams by modulating the amplitude.

To achieve a practical electro-optic effect, the molecules must be aligned in a matrix so that there is no center of symmetry. Unfortunately, electrostatic interactions between the chromophores cause them to orient themselves in ways that sap the material's light-modulating ability.

To overcome this problem, Dalton and Robinson performed theoretical studies that suggested that undesirable electrostatic interactions could be minimized by making the chromophores thicker in the middle—that is, ellipsoidal in shape. This work led to CLD-1, which has a bulky isophorone moiety midway between the electron-donating and electron-accepting groups.

Dalton and coworkers also synthesized a related series of "FTC" molecules that contain a substituted thiophene in the middle. Susan Ermer and coworkers at Lockheed Martin's Advanced Technology Center in Palo Alto, Calif., incorporated modified FTC molecules in a modulator and observed performance similar to CLD-1's. Ermer's work will soon be published.

For Dalton, CLD-1 and FTC were just the beginning. His group is now working with even more impressive electro-optic materials. The latest chromophores under study have dendritic groups that make the molecules more spherical. This serves to almost double their electro-optic activity, and as a result they require even lower drive voltages, Dalton tells C&EN. He expects drive voltages will continue to drop, "conceivably into the low-millivolt range."

Ron Dagani