With regards,
P.W.

LARGE ELECTROCLINIC EFFECT IN NEW LIQUID CRYSTAL MATERIAL[a]

Paul A. Williams[*,†], Noel A. Clark[†], M. Blanca Ros[‡],
Rohini T. Vohra[§], David M. Walba[‡], and Michael D. Wand[§]

[*]National Institute of Standards and Technology
Boulder CO 80303-3328

[†]Department of Physics, Condensed Matter Laboratory,
University of Colorado, Boulder CO 80309-0390

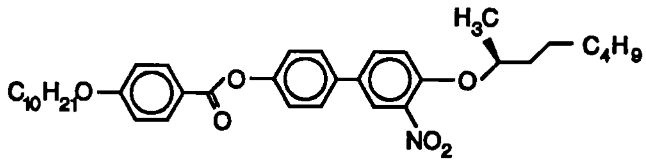
[‡]Department of Chemistry and Biochemistry
and Optoelectronic Computing Systems Center,
University of Colorado, Boulder CO 80309-0215

[§]Displaytech Inc.
2200 Central Avenue, Suite C
Boulder CO 80301

ABSTRACT We report a new liquid crystal material (W317) which has an unusually large electroclinic effect in a phase tentatively identified as smectic A. We show electroclinic tilt angles as large as 21°, and measurable tilt angles over a 40°C temperature range.

The electroclinic effect was first described by Garoff and Meyer in 1977.[1,2] We will consider the effect as it occurs in the chiral smectic A phase, where the liquid crystal molecules are oriented with their long molecular axis or director (**n**) parallel to the layer normal. An electric field **E** applied parallel to the smectic layers couples to the transverse component of the molecule's permanent electric dipole (**p**). This biases the rotation of the molecules about their long axes since **p** tends to be parallel to the applied field. The chirality of the molecules requires that the plane defined by **p** and **n** is not a mirror plane. The result is that the free energy of the molecule is not a symmetric function of molecular tilt. So, for a non-zero applied electric field, the average molecular tilt in the plane perpendicular to **E** is non-zero. It also turns out that the tilt is a linear function of the field (for small fields).

We recently measured an unusually large electroclinic effect in a newly synthesized material (which we refer to as W317). This material has the structure



The electroclinic effect is seen in what has been tentatively identified as the smectic A phase. The texture as viewed through a microscope resembles a smectic A phase. However, preliminary x-ray scattering data does not seem to support this identification.[b] With this in mind, we describe the phase diagram as

$$X \rightarrow (41°C) \rightarrow Sm\ A? \rightarrow (76°C) \rightarrow Iso.$$

It should be noted that the so-called smectic A phase can be supercooled to temperatures as low as 16 or 18°C for short times. This was done to take some of the data shown in this paper. The polarization of W317 was measured to be around -130 nC/cm^2.[c]

For this experiment, a homogeneously aligned W317 cell was prepared using patterned indium-tin-oxide coated glass slides which were spin-coated with a nylon alignment layer and buffed unidirectionally. We measured the cell to be between 2 and 3μm thick.

Using the apparatus shown in figure 1, we measured the electroclinic tilt angle as a function of both applied field and temperature. The temperature was controlled by placing the cell in a computer controlled hot stage. A sinusoidal voltage of amplitude V_0 and frequency 200Hz was applied to the cell. This caused the molecules to tilt between $+\theta_0$ at $V=+V_0$ and $-\theta_0$ at $V=-V_0$. The applied voltage and the output signal from the detector were monitored on an oscilloscope. We rotated the cell in figure 1 until the transmission was a minimum at the point in time corresponding to $V=+V_0$. This meant that the molecular axis was parallel to one of the polarizers when the applied voltage was a maximum ($V=+V_0$). We then rotated the cell until a minimum transmission at $V=-V_0$ was reached. We measured the angle through which the cell was rotated to find $2\theta_0$. By changing the amplitude of the sine wave and the temperature of the cell, we measured θ as a function of V and T. Results are shown in figures 2 and 3.

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[b] A. Rappaport, Department of Physics, Condensed Matter Laboratory, University of Colorado, Boulder CO 80309-0390, private communication.

[c] Measured by R. Shao, Department of Physics, Condensed Matter Laboratory, University of Colorado, Boulder, CO 80309-0390.

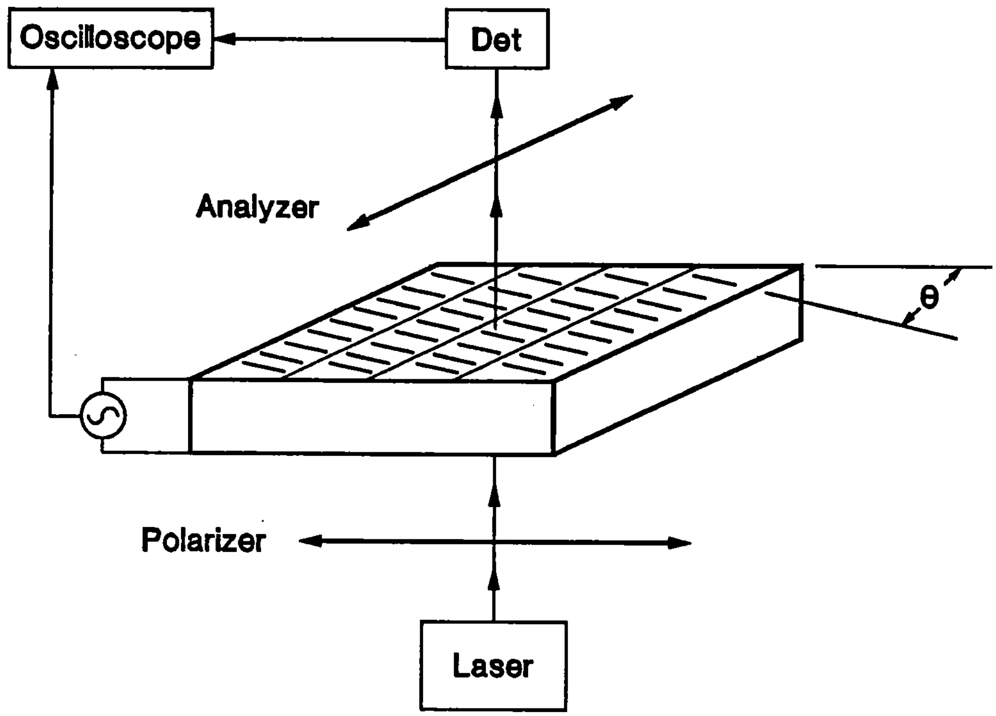

Figure 1. Experimental orientation of the cell between crossed polarizers.

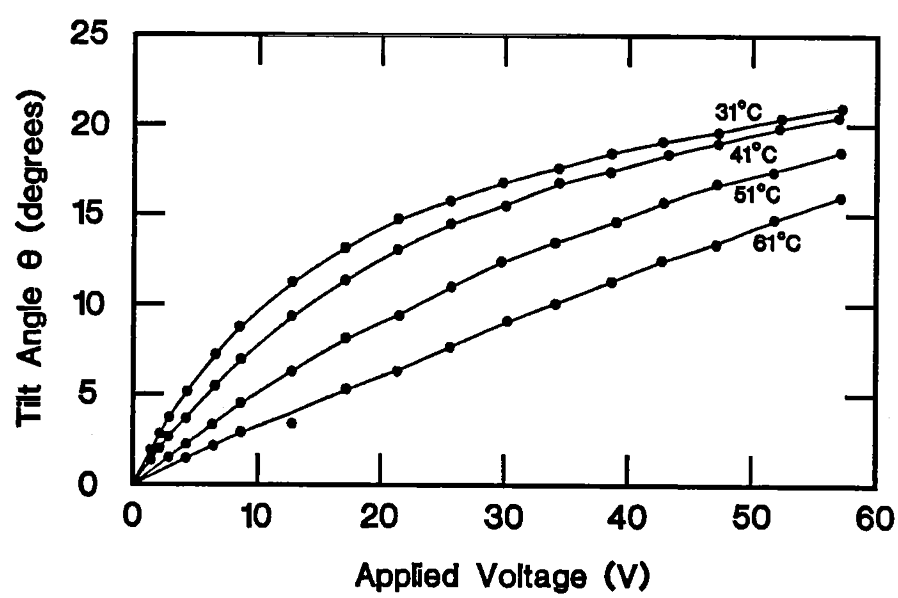

Figure 2. Electroclinic tilt vs applied voltage at several temperatures.

Figure 2 shows that unusually large tilt angles are achieved by relatively small voltages (fields) and that tilt angles in excess of 21° are possible. The measured tilt as a function of field is linear in field for small fields or high temperatures, and nonlinear for larger fields or lower temperatures. This agrees qualitatively with theoretical predictions[3,4] and experimental work on other

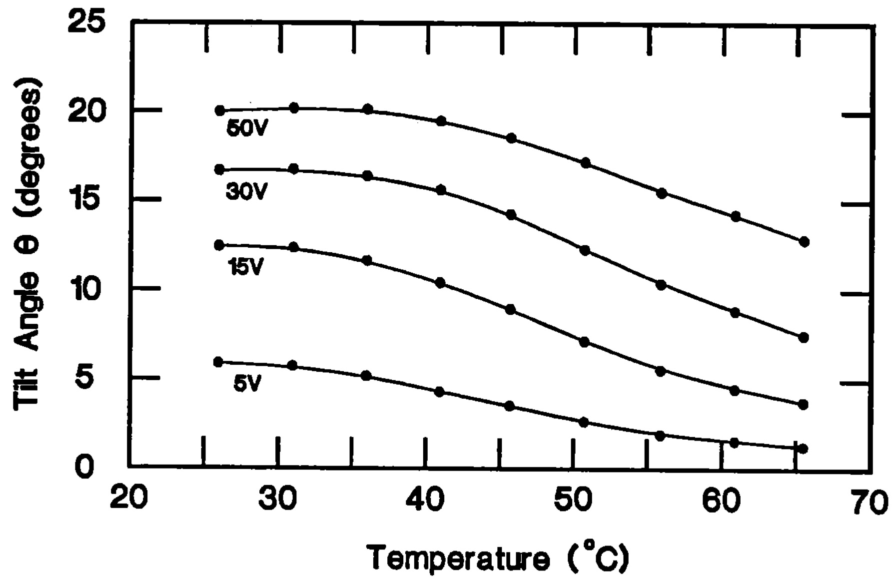

Figure 3. Electroclinic tilt vs temperature at various applied voltages.

electroclinic materials.[3,5,6] However, the behavior of the tilt vs temperature plots of figure 3 was unexpected. Typically, an electroclinic tilt vs temperature graph is concave up, with the tilt increasing dramatically as the temperature is reduced toward the bottom of the smectic A phase.[4,5,6] Although W317 shows this concave-up behavior at higher temperatures, the steep increase at lower temperatures is not seen. As a matter of fact, the tilt becomes almost independent of temperature at the lowest temperatures. This unusual behavior will be explored in the future.

This work supported in part by the Office of Naval Research.

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Ferroelectrics, 1991, Vol. 121, pp. 143–146
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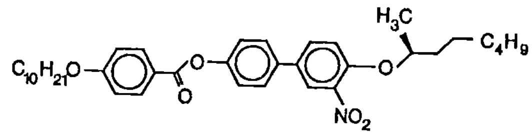

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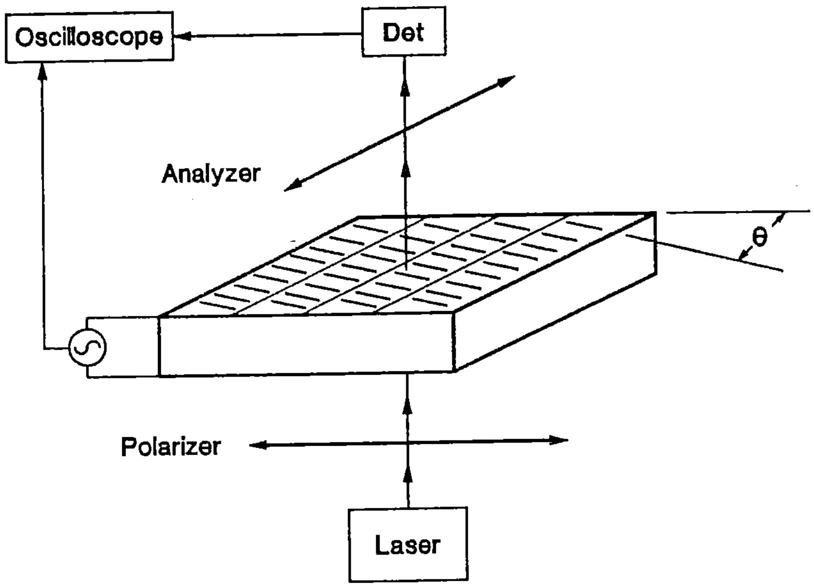

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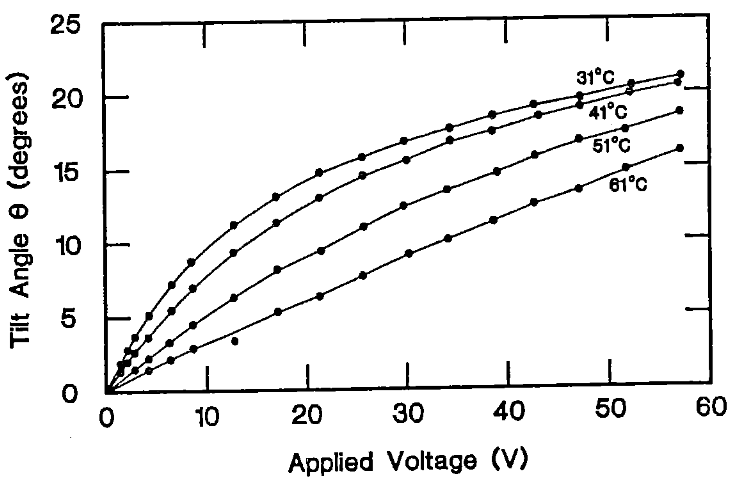

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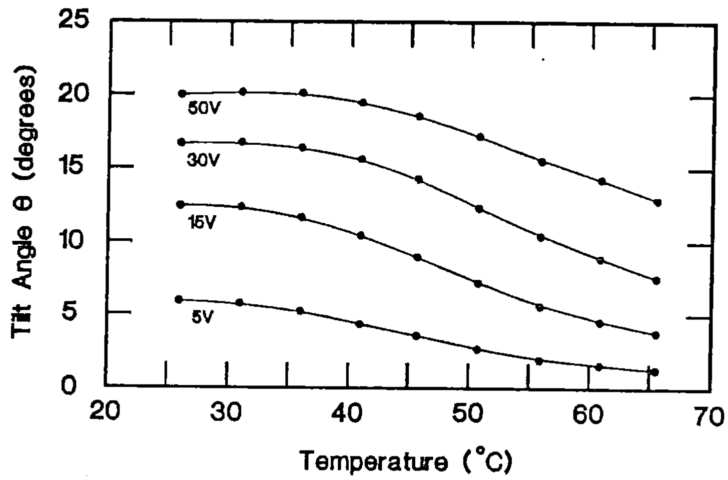

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