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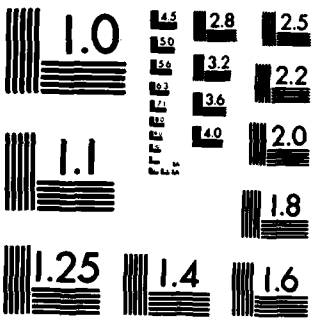

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We undertook the study of the interaction of nematic liquid crystals with inhomogeneous solid surfaces, in the attempt to better understand surface interactions and to fabricate new kinds of devices with novel surface alignment techniques. Along with the surface studies, we considered the optical properties of the new liquid crystal configurations we were attempting to fabricate, and new electro-optical effects that might be achieved.

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20. ABSTRACT CONTINUED:

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Final Report

Robert B. Meyer

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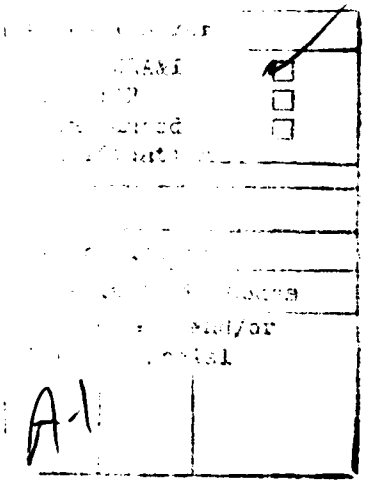

Statement of the problem studied

We undertook the study of the interaction of nematic liquid crystals with inhomogeneous solid surfaces, in the attempt to better understand surface interactions and to fabricate new kinds of devices with novel surface alignment techniques. Along with the surface studies, we considered the optical properties of the new liquid crystal configurations we were attempting to fabricate, and new electro-optical effects that might be achieved.

The new surface treatments that we investigated were ones consisting of a microscopically inhomogeneous array of different aligning agents. The cases studied in detail were that of a surface which aligns the nematic director perpendicular to itself, on which we created a random array of spots, a few hundred angstroms in diameter, in which the director is parallel to the surface, and the inverse, i.e., spots of vertical alignment on a horizontal aligning surface. The competition between parallel and perpendicular alignment was anticipated to result in some oblique average alignment, and to offer the possiblity of bistable alignment of the director, in two or more oblique directions. The possibilities of oblique alignment and bistability were the two fundamentally new properties that could lead to new device applications.

Summary of Results

I. Optical properties of spatically inhomogeneous NLC structures:

(a) We first studied electromagnetic wave propagation in a periodically bent NLC. By expressing the fields in terms of antipotentials with a generalized Lorentz gauge condition, the extraordinary wave equation was shown to have the form of Inc's equation, for which we presented the first reported general solution. We also discussed the normalized solution and characteristic equation of Ince's equation. The extraordinary wave was shown to have the form of a Bloch wave. The equivalence of the field and antipotential descriptions was shown for the case of normal incidence. The cases of propagating and totally reflected waves were also discussed.

(b) We also studied the optical properties of a single domain bent NLC in an external field. In a bent NLC, the depth of the transitional bent layer depends on the external field and NLC parameters and hence forms a model system for studying the electro-optics of inhomogeneous anisotropic media. The wave satisfies Heun's equation for the case of normal incidence. By approximating the wave equation using an Epstein dielectric profile, we obtained the approximate expressions for the reflection and transmission coefficeients. The results were compared with the numerical results using Holmes' method for studying wave propagation in a birefringent multilayer medium.

(c) Recently, we developed a general formalism for finding the electromagnetic fields in a layered-inhomogeneous NLC planar structure using the geometrical optics approximation. Explicit expressions for the field in the first- and second-order approximation were obtained. The criterion for the approximation to be valid was found. We also discussed the weak reflection and the interpolation formula for the reflectivity by a general layer. Exactly solvable profiles and nonreflecting profiles for normal incidence were

obtained. The results were applied to the cases (a) and (b).

In the above studies, the wave and Poynting vectors in the inhomogeneous anisotropic medium were shown to depend not only on the angle of incidence but also on azimuthal angle of the incident wave. However, the critical angle for total reflection to occur was shown to depend only on the angle of incidence and to be independent of the azimuthal angle of the incident wave.

II. Optical-field-induced molecular reorientation and bistability in nematic and smetic-C liquid crystals:

(a) We obtained the exact solution for describing the optically induced spatial reorientation of the director of a hemeotropically oriented NLC for the case of normal incidence. The criterion for the physical parameters that indicate whether the transition is first- or second-order was obtained. The hysteresis accompanying the first-order transition was discussed and an experiment was proposed to observe, for the first time, a first-order Freedericksz transition in NLCs. The dynamics of the transition were also discussed and an approximate solution was given. Detail comparisons between our approach, the Durbin approach, the Zel'dovich approach, and a self-consistent geometrical optics approximation approach were made.

(b) We also obtained the Euler equations for describing the director in the optically induced molecular reorientation of a smetic-C liquid crystal in an external field. The alignment effect was shown to be localized and not to produce point defects. Analytic expressions were given explicitly in the small-distortion regime. The transient response of molecular reorientation was shown to have exponential time dependence with a response time of the order of milliseconds. We proposed that, experimentally, the transition can be quantitatively measured by the reflectivity or transmissivity of a normally incident probe beam. The optical reflectivity and transmissivity from a typical smetic-C film were also calculated.

III. Multistable orientation of a NLC cell induced by the interaction of NLCs with homogeneous surface and external fields:

The effects of a short-range, arbitrary strength homogeneous interfacial potential on the molecular reorientation induced in a NLC cell by dc and optical fields were discussed and the exact solution obtained. The procedure for determining the threshold, the saturation, and the parallel-state-maintenance fields were presented. We also discussed the first-order transition and proposed three simple experimental methods manifesting the effects of surface interactions. The criterion for the transition to be first order at any field was given. Based on the existing experimental results, the possibility of surface induced first-order transitions was discussed and three simple empirical approaches were suggested for observing multistable orientation. The early results on the dc field induced Freedericksz transition and the inadequacy of the usual experimental observational methods (phase shift and capacitance measurements) were also discussed.

IV. Alignment of liquid crystals by inhomogeneous surfaces.

To form inhomogeneous surfaces we used the technique of evaporating metals onto warm substrates to form metal "island" films, with structure in the size range of hundreds of angstroms. Our first efforts with silver gave inconsistent

and unreliable results. We then switched to aluminum, and achieved the desired results. We were able to vary the thickness of the aluminum coating and thus its coverage of the glass, to make structures of varying ratios of vertical to horizontal aligning area. By applying the aluminum coating on top of a surface treated with obliquely evaporated SiO and silane coupling agent to promote vertical alignment, and then exposing the aluminum coated surface to a glow discharge in air, which removes the silane in between the aluminum islands, and finally removing the aluminum with weak HCl, we achieved an array of islands of silane (vertical alignment). Detailed results are discussed in a publication. Oblique alignment of the nematic director at the surface was achieved, with the tilt angle depending on the coverage of the aluminum island film. There were two energetically equivalent tilt directions.

V. Voltage tunable phase grating.

Using a mesh mask, and evaporating a thick coating of aluminum through it, we were able to generate a very fine two dimensional periodic pattern of vertical alignment spots on a horizontal alignment background. Using this plate as one side of a sandwhich cell, and a perpendicular alignment plate as the other side, with both plates being indium tin oxide coated, we were able to construct an electric field controlable phase grating. A publication of this result is in preparation.

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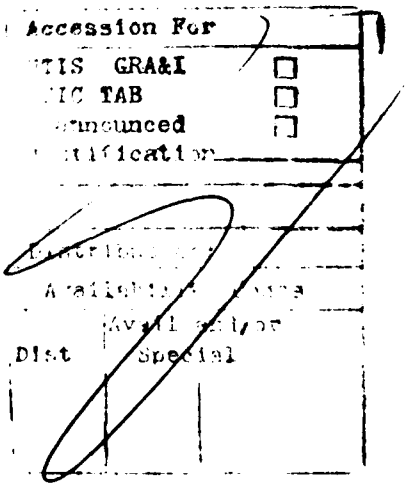

Participating Scientific Personnel

Brian Friedenreich - Undergraduate Assistant

Robert Gorczyca - Undergraduate Assistant

Alan Hurd - Postdoctoral

Franklin Lonberg - Graduate Student

Robert B. Meyer - Principal Investigator

Hiap Liew Ong - Graduate Student, Ph.D., 1984

Benedict Schimmil - Undergraduate Assistant

George Srajer - Graduate Student

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