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Observation of Squint—A Nonlinear Feature of Flow Patterns in Nematics

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Evidence is presented for the existence of squint as previously predicted by Ben-Abraham. A quantitative measure of this nonlinear feature of electrohydrodynamic flow patterns as observed in MBBA is presented.

I. INTRODUCTION

Since the discovery of the now well-known Williams domain, flow patterns in nematics have been a topic of considerable interest.[1–6] More recently interest has been focussed upon the study of non-linear phenomena[7–16] in these flow patterns. Ben-Abraham[14–16] has proposed a non-linearity which he refers to as squint. This distortion is manifested as a change in the normal roll pattern of a sample with standard Williams domain geometry. In his earlier work,[14] Ben-Abraham does a one-dimensional calculation in which he predicts a distortion term proportional to $\psi\psi'$ where $\psi = \partial\phi/\partial x$. (Here ϕ is the director angle relative to the rubbing direction, x). This distortion is shown schematically in Figure 1. In a later work,[15] Ben-Abraham performs a two-di-

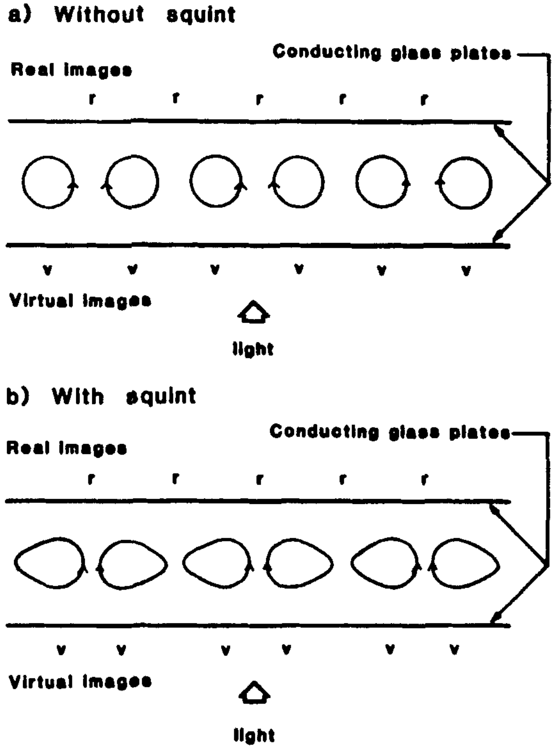


FIGURE 1 Schematic illustration of squint.

mensional calculation and finds that squint also occurs across the sample. In either case, squint causes the virtual images to pair while the real images remain equidistant. We report here the positive results of our experiments to detect this squint in the nematic liquid crystal *p*-Methoxy-benzylidene-*p*-*n*-Butylaniline (MBBA).

II. EXPERIMENTAL

The experimental set-up is shown in Figure 2. The sample is held between conducting glass plates that have been coated with polyvinyl alcohol and rubbed to achieve homogeneous alignment. The sample holder is free to rotate about three axes and can be translated perpendicular and parallel to the laser beam. The polarized laser beam is rotated for maximum contrast and the analyzer set parallel to the polarization direction of the laser. The camera can be removed so that one

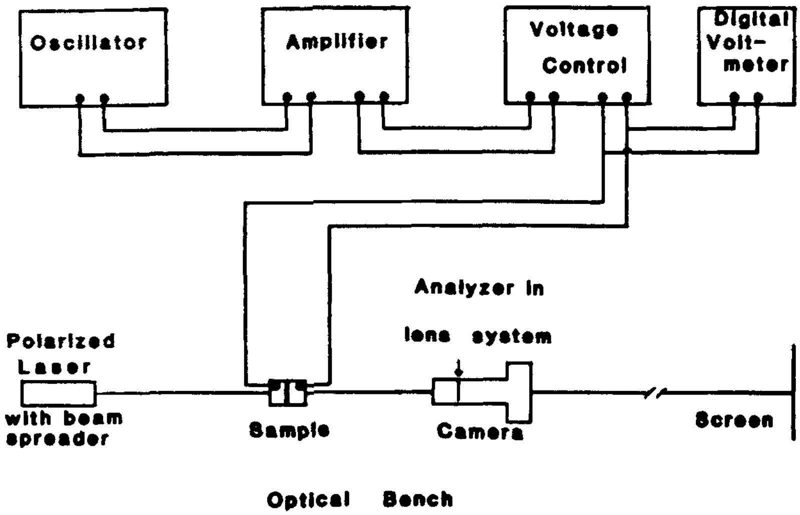


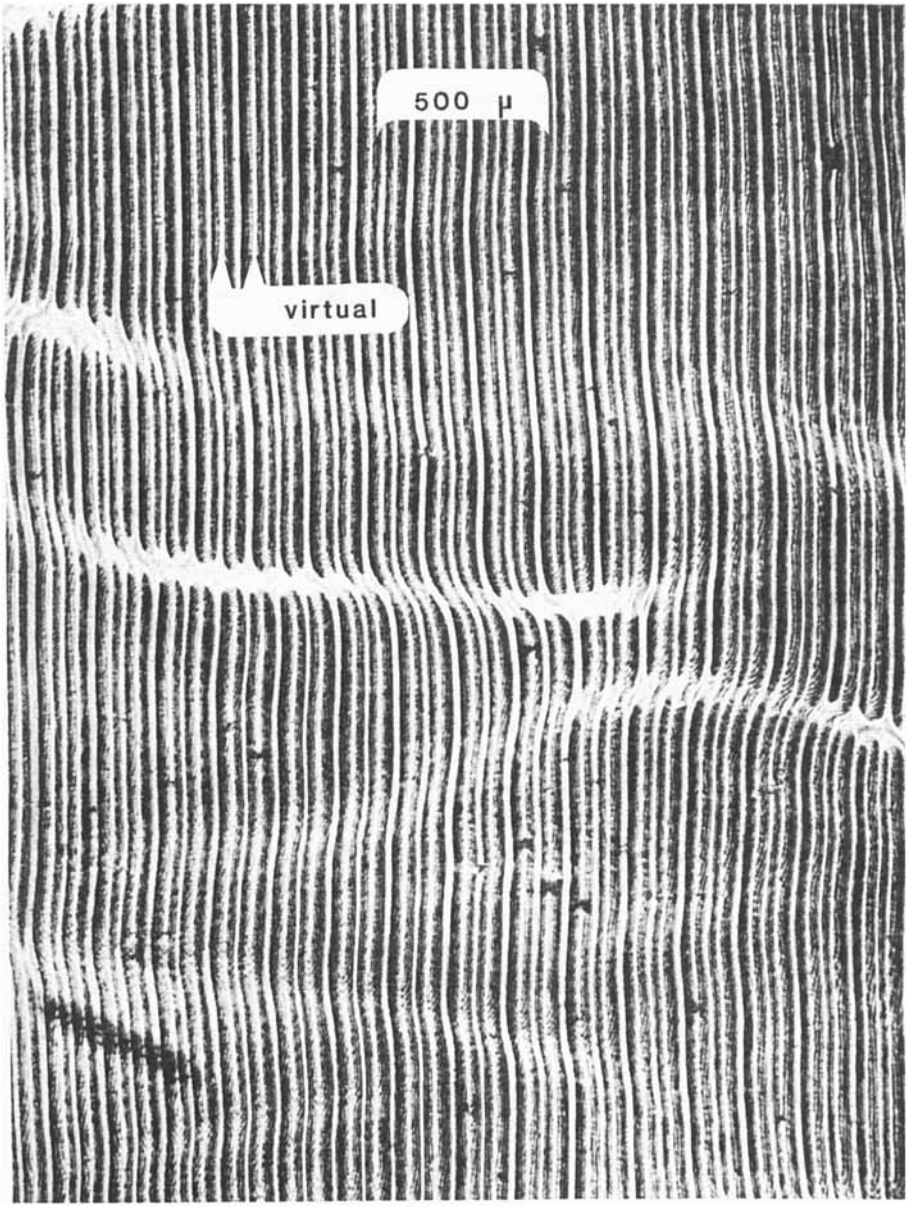
FIGURE 2 Experimental arrangement.

may observe the diffraction pattern due to the electrohydrodynamic instability. This pattern was used to help align the sample relative to the laser beam. Kashnow and Bigelow[17] have shown that non-normal incidence of the laser beam onto the sample results in extra fringes in the diffraction pattern. We have observed these fringes and adjusted the sample, via rotation about an axis in the plane of the sample parallel to the aligned molecules, to minimize the intensity of these fringes. We also rotated the sample about the axis in the plane of the sample perpendicular to the aligned molecules until the even fringes appeared sharp and symmetrical to the eye.[18] The sample was then photographed. One can focus either on the real or virtual image by translating the sample parallel to the beam. Different parts of the sample can be photographed by translating perpendicular to the beam.

III. RESULTS AND DISCUSSIONS

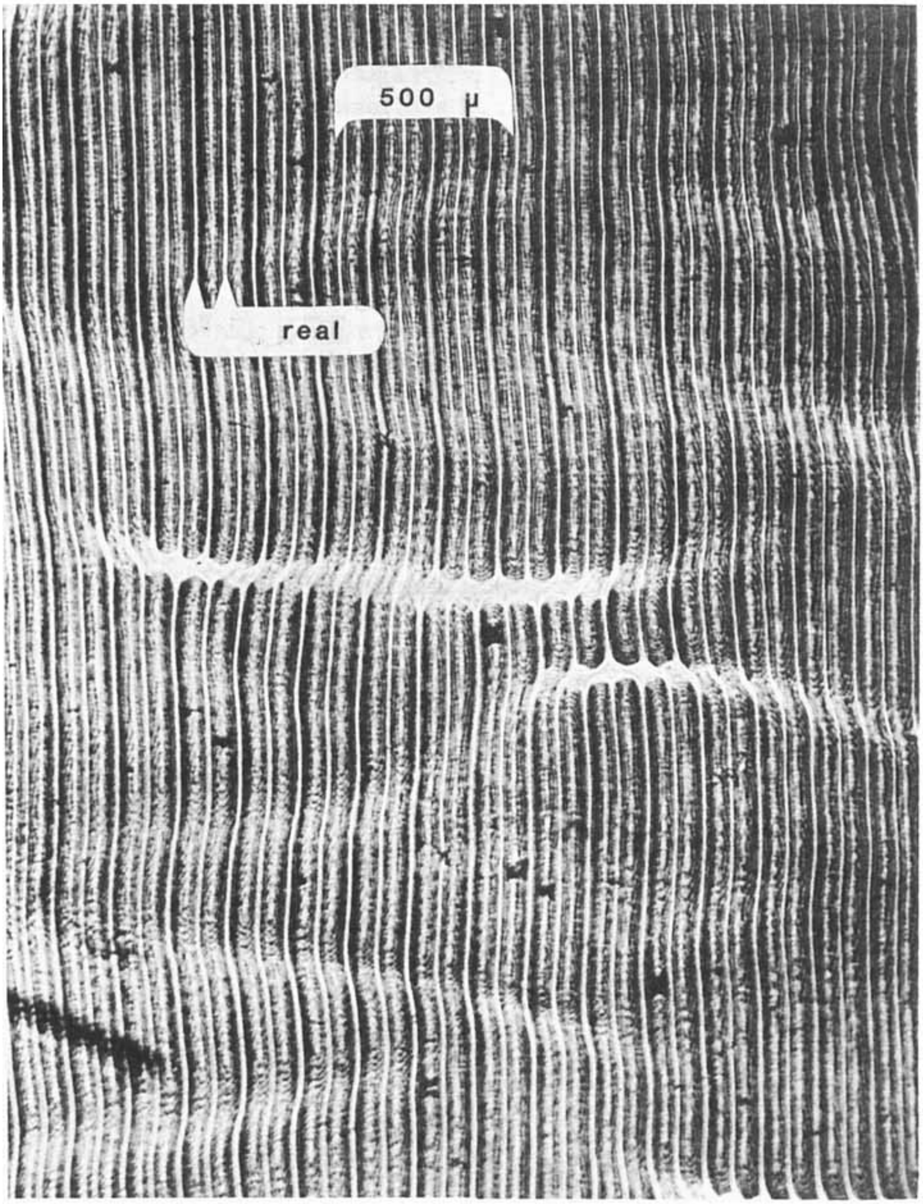
Typical patterns are shown in Figure 3. The line spacings are measured on an image of the 35 mm negative projected on a screen. If S_1 is the average of alternate spaces and S_2 is the average of the interdigitated spaces then one can define an anisotropy factor (in percent)

$$A \equiv |(S_1 - S_2)/(S_1 + S_2)| \times 100\%$$



(a)

FIGURE 3 Typical textures; (a) virtual image; (b) real image.



(b)

The problem of observing squint is then reduced to the problem of measuring A. If one refers to Figure 1b, one sees that the real images are predicted to be equally spaced, i.e., $A = 0$, and the virtual images are predicted to be paired, i.e., $A \neq 0$. In the latter case, the size of A is a measure of the amount of squint present.

One needs to identify which lines in the picture belong to the real or virtual image since it is impossible with our set-up to focus on one image without observing the other slightly out of focus (i.e., our depth of field is not narrow enough even at full open aperture). The images are identified by observing which lines go in and out of focus as the sample is translated relative to the camera. One finds the virtual image on the laser side of the sample and the real image on the camera side. Arrows are used in Figure 3 to indicate the stripes associated with the respective patterns. The results of several measurements are shown in Table I. The average values of A for the real and virtual data, respectively, are 2% and 9%. Thus we observe a definite pairing in the virtual images, while the real images show little or no pairing within experimental error. One should note that MBBA was chosen as the sample since it is in the nematic phase at room temperature. From the point of view of squint observation, it is a poor sample choice. Squint is predicted to be proportional to K_{33}–K_{11}, and these elastic constants are

TABLE I

Anisotropy factors for various samples and conditions

Sample number	Applied voltage	Freq (Hz)°	A (%) (Real)	A (%) (Virtual)
1	6.6	25	0.0	7.9
1	6.8	25	2.2	6.7
1	7.0	25	4.4	10.6
2	8.5	25	3.0	10.2
2	9.0	25	0.0	8.0
1	7.4	50	1.0	8.9
1	7.6	50	1.1	9.9
1	8.0	50	1.0	8.0
2	9.0	50	2.0	8.3
2	9.9	50	1.0	8.9
1	8.5	60	1.2	8.4
1	8.9	75	5.1	12.8
1	9.0	75	2.6	11.7
1	9.2	75	1.3	11.7
2	11.7	100	2.2	9.6
2	12.1	100	2.1	8.7
3	13.7	100	1.2	9.2

Note: Data taken on three different samples.

nearly equal for MBBA,[19] so that only a small effect is expected. We plan subsequent experiments using compounds that have greater differences in their elastic constants.

In summary, we have presented evidence which we believe indicates that we observed the squint effect predicted by Ben-Abraham. Quantitative correlation of squint with the anisotropy of the elastic constants remains to be done.

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