universal coupling matrix element given by Olson and Salop[3] give essentially the same n values for the present cases.

In summary, we have shown that the electron capture from rare-gas targets by slow, highly charged ions proceeds very selectively, populating one or two main shells which are associated with the energy balance of the electronic levels according to a quasiresonant over-barrier transition. The n values populated agree well with the classical barrier model, although the use of a universal transition probability to predict cross sections from this model is shown to be inadequate.

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Experiments on Director Waves in Nematic Liquid Crystals

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In a homeotropic nematic cell, a solitarylike director wave is excited by a mechanical method. Three photographs of the wave propagation process and measured velocity-time dependence curves are presented. By means of the interference patterns of focused polarized light, it was found that the dark lines observed in white-light photographs correspond to a perpendicular alignment state of the director.

PACS numbers: 61.30.-v, 47.35.+i

Discussions about director waves began in 1968.[1,2] Leslie gave a good summary in 1979.[3] More recently, there have been two preliminary experimental reports on director waves by the author,[4,5] and a theoretical discussion by Lin and Shen.[6]

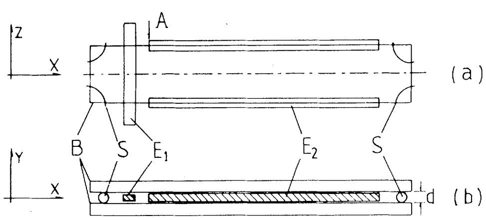

FIG. 1. A sketch of the liquid-crystal cell.

In these experiments, the liquid-crystal cell consists of two polished glass plates (B) of dimensions $0.5\times5\times30$ cm^3 (Fig. 1), with the cell thickness $d=50\pm5$ μm, fixed by four spacers (S). E_1 is a Mylar film 20 μm thick, which serves as exciter. E_2 are Mylar films 30 μm thick for reducing the flow of liquid crystal in the z direction. The coordinate system used in later discussion is sketched on the left-hand side of Fig. 1. The arrow marked by A denotes the origin of

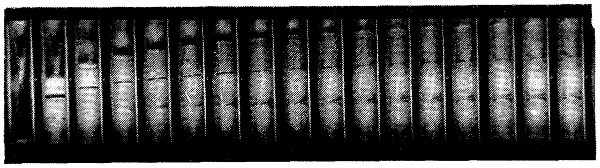

FIG. 2. Propagation process of the wave. Light source: white; $\bar{u} = +2.25$ mm/sec.

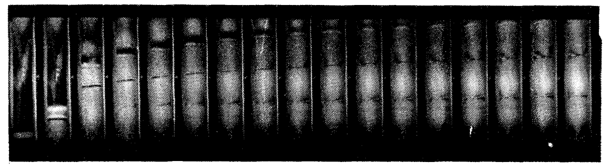

FIG. 3. Propagation process of the wave. Light source: white; $\bar{u} = -2.25$ mm/sec.

the x axis. The dashed line in Fig. 1(a) will be explained in the second and third experiments below. A pretreatment was applied to the base plates with licithin for the perpendicular alignment of the director. When the exciter (E_1) moves parallel to the x direction with a certain velocity, the propagation of three black lines can be seen in polarized white light. The material used is N-(*o*-methoxybenzylidene)-*p*-butylaniline (MBBA) (supplied by the Institute of Chemical Reagents of Beijing). The following experiments were performed at temperature 25 °C. The sample was illuminated from below.

In the first experiment, a stroboscopic lamp (model PSZ, manufactured in Shanghai) operating at 10.0 Hz illuminated the sample with a spectrum of nearly white light. A polarizer was placed below the liquid-crystal cell with direction of polarization at an angle of 45° to the x axis, and a second analyzer was placed above the liquid-crystal cell with the direction of polarization perpendicular to the first. Let s be the displacement of the exciter along x direction, t the time of motion, $u = ds/dt$ the velocity of the exciter. The average velocity of the exciter is $\bar{u} = +2.25$ mm/sec for Fig. 2, $\bar{u} = -2.25$ mm/sec for Fig. 3. The motion of the exciter is linear and uniform except at the beginning and the end. The motion of exciter is restricted to $s = 9$ mm.

It can be seen from either Fig. 2 or Fig. 3 that there are three dark lines propagating along the positive x direction in a similar way irrespective of the sign of u. The position x of the dark lines was measured at different times from Fig. 2, and the x-t curves were plotted in Fig. 4. Because the light pulses are not synchronized to the motion of the exciter, there is some uncertainty of the starting time of the exciter (which is taken as the time origin). However, by referring to other experiments with higher stroboscopic frequencies, the time origin of Fig. 4 is found to have an accuracy of ± 25 ms. The velocities $\bar{c}$ of the dark lines are calculated from Fig. 4, and the $\bar{c}$-t curves are plotted in Fig. 5. The velocity of different dark lines is 10–19 cm/sec at the beginning and drops to 2–5 cm/sec after a second. Some experiments with various $\bar{u}$ were also carried out in the range of $\bar{u} = 0.5$–3 mm/sec. There are also three dark lines propagating. The number of dark lines is reduced as the thickness of the exciter is decreased.[7]

In the second experiment, focused polarized monochromatic light was used to observe the interference patterns at two positions along the axis of the cell (the dashed line in Fig. 1) with $x = 13$ cm and $x' = 14$ cm, respectively. The wavelength of light is 6328 Å. The positions of the polarizer and of the analyzer are the same as in

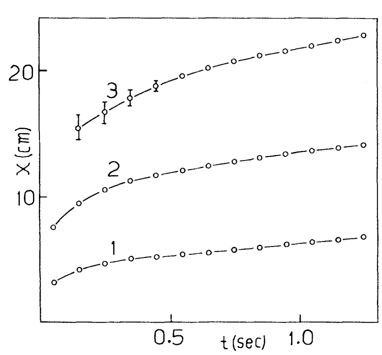

FIG. 4. x-t dependence curves of the three dark lines.

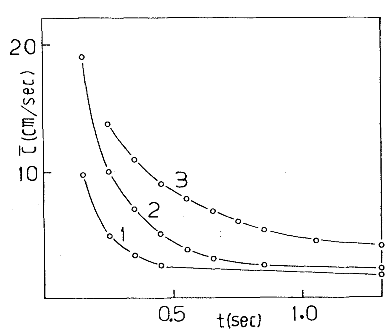

FIG. 5. $\bar{c}$-t dependence curves of the three dark lines.

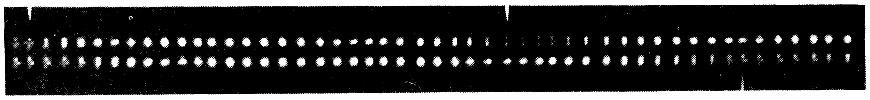

FIG. 6. Interference patterns of focused monochromatic polarized light at two fixed points: $x = 13$ cm, $x' = 14$ cm.

the first experiment. The mean velocity $\bar{u}$ of the exciter is $+2.25$ mm/sec. The light is stroboscopic with a frequency of 30 Hz. Figure 6 was recorded with the photographic film moving along the z direction. The dots in the upper row are patterns at x, the lower row those at x' taken simultaneously. The state at x is initially (at time zero) in the undisturbed state (denoted by the first pointer at the left-hand side) in which the optical axis of the cell (and also of the director) is parallel to the light and perpendicular to the glass plates. It then becomes turbid and returns to the perpendicular state at $t = 0.94$ sec (marked by the second pointer in the upper row). At x', the perpendicular state reappears at $t' = 1.37$ sec (marked by the third pointer in the lower row). The mean velocity of propagation of this state calculated from the above data is $c = (x' - x)/(t' - t) = 2.3$ cm/sec. With reference to Fig. 4, it was found that this state corresponds to the second dark line. The same method was used to examine the first and third dark lines with similar results.[7] The second experiment proves that the dark lines in Figs. 2 and 3 are in the perpendicular alignment state.

In the third experiment, monochromatic light was used to record the wave process. A pencil of laser light (of wavelength 6328 Å) is widened to a line by a glass rod. Observation is restricted on the dashed line in Fig. 1. Stroboscopic frequency of light is 15 Hz. Other experimental conditions are the same as those used in Fig. 2. The result is represented by Fig. 7.

From Fig. 7 we can calculate the difference of optical path of ordinary light and extraordinary light corresponding to different x and t. In fact, if one assumes the director to be in the (x,y) plane and lets θ be the angle between the director and the y axis, the light intensity transmitted through the cell is given by[8]

$$I = I_0 \sin^2 \tfrac{1}{2}\delta, \tag{1}$$

where I_0 is the light intensity when $\delta = \pi$ and δ is the phase difference between the ordinary and extraordinary light given in this case by

$$\delta = (2\pi/\lambda_0)\int_{-d/2}^{d/2} [n(\theta) - n_0]\,dy. \tag{2}$$

Here, n_0 and n are the refractive indices of the ordinary and extraordinary light (with wavelength λ_0 in vacuum), respectively. From (1) and (2), it is clear that the light intensity measured in the first experiment in which incident white light is used is the sum of the intensities from each wavelength as measured in the third experiment. The third experiment therefore contains more information than the first one and provides a means to deduce or examine the theoretical distribution of θ. By comparing Figs. 2 and 6 it is found that there is a rapid variation of the direction of the director on the two sides of the first and second dark lines.[7]

Experiments similar to the first one have been performed in the whole nematic range of MBBA (21–46 °C) and in all these cases there are always dark lines generated. Dust particles near the dashed line in Fig. 1 in the cell are observed under a microscope to move in the same direction as E_1. When the two long sides of the cell are sealed, dark lines and similar results are still obtained.[7]

The three experiments above confirm the existence of director waves in nematics. These are incompressible waves because their velocities are much smaller than that found in ordinary compressible waves in fluids. These two types of (incompressible and compressible) waves also exist in many different kind of fluids, e.g., superfluid, plasma, etc.

Other details and discussions on the physics of these experiments will be presented elsewhere.[7]

There is a related theoretical explanation by

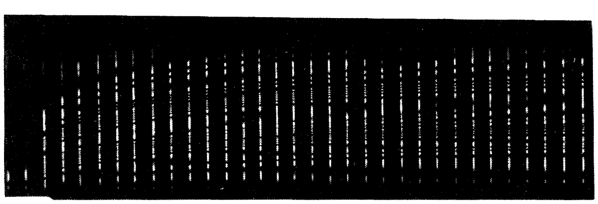

FIG. 7. Propagation process of the wave. Light source: monochromatic light. $\lambda_0 = 6328$ Å, $\bar{u} = +2.25$ mm/sec.

Lin *et al.*[9] in which the dark lines are interpreted as solitons.

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Soliton Propagation in Liquid Crystals

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Soliton propagation in nematic liquid crystals under shear is shown to be possible and studied theoretically. Calculations including those pertaining to the modulation of monochromatic or white light passing through such a liquid-crystal cell are presented. Recent experiments are interpreted accordingly and are in good agreement with the theory presented here.

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Solitons are important and have been found in various objects ranging from celestial bodies to laboratory systems.[1,2] However, unlike the first observation of solitons in shallow water by Scott Russell, many of the recent experimental evidences of solitons in condensed matter are indirect in nature. The experiments[3] on the ordered fluid ^{3}He are no exception. In this regard, we note that in another type of ordered fluid, viz., liquid crystal, because of the strong coupling of the director with light, it may be possible to observe the motion of the molecules and the solitons rather directly.

Discussions of solitons in liquid crystals[4] was first given by Helfrich[5] and subsequently by de Gennes,[6] Brochard,[6] and Leger.[7] In their work in nematics, the solitons (called "walls") are magnetically generated and are small in width (e.g., a few microns). Experimentally, the observation[7] of these solitons is delicate and a polarizing microscope has to be used. Recently, there has been more but still limited attention[8] paid to the role of solitons in the physics of liquid crystals.

In this Letter, we first point out and discuss a new case in liquid crystals, viz., nematics under uniform shear, in which solitons can exist and propagate. In contrast to the magnetic case[5-7]

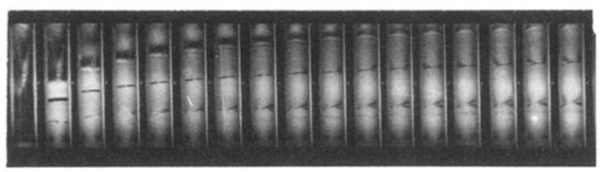

FIG. 2. Propagation process of the wave. Light source: white; $\bar{u} = +2.25$ mm/sec.

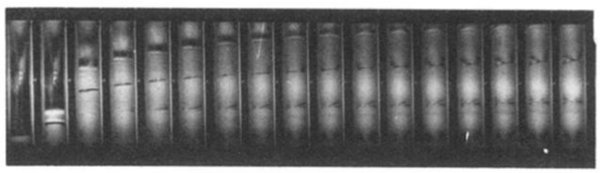

FIG. 3. Propagation process of the wave. Light source: white; $\overline{u} = -2.25$ mm/sec.

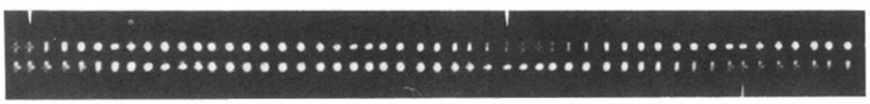

FIG. 6. Interference patterns of focused monochromatic polarized light at two fixed points: $x = 13$ cm, $x' = 14$ cm.

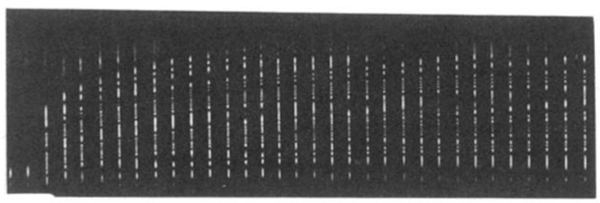

FIG. 7. Propagation process of the wave. Light source: monochromatic light. $\lambda_0 = 6328$ Å, $\bar{u} = +2.25$ mm/sec.