United States Patent [19]

Kalmanash et al.

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[45] **Date of Patent: Sep. 13, 1988**

[54] **METHOD AND APPARATUS FOR MULTI COLOR DISPLAY**

[75] Inventors: **Michael H. Kalmanash,** Los Altos; **James L. Fergason,** Atherton, both of Calif.

[73] Assignee: **Kaiser Aerospace and Electronics Corporation,** Oakland, Calif.

[21] Appl. No.: **872,520**

[22] Filed: **Jun. 10, 1986**

[51] **Int. Cl.**[4] **G02F 1/13;** G02B 5/30; G02B 1/23

[52] **U.S. Cl.** .... **350/347 E;** 350/335; 350/347 R; 350/378; 350/388

[58] **Field of Search** .... 350/347 R, 347 E, 335, 350/378, 387, 388, 389, 391; 358/242, 58

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,407,017	6/1964	Fleisher et al.	350/388
3,781,465	12/1973	Ernstoff et al.	350/335
4,385,806	5/1983	Fergason	350/347 R
4,582,396	4/1986	Bos et al.	350/347 E
4,674,841	6/1987	Buzak	350/347 E

Primary Examiner—Stanley D. Miller
Assistant Examiner—Huy V. Mai
Attorney, Agent, or Firm—Marvin H. Kleinberg

[57] **ABSTRACT**

An apparatus and method for producing a color display from a substantially monochromatic source utilizes a liquid crystal cell combination together with a plechroic filter to differentially polarize the light components comprising the light emitted from the source. The liquid crystal cells are connected in push-pull fashion to individually retard light by one fourth of a wave as a function of the control signal applied to them. A fourth wave plate followed by a linear polarizer completes the optical combination. A signal at a first level applied to the cells causes transmission of one component color and blocks the other. A signal at a second level blocks the one component color and transmits the other. An intermediate level signal transmits both colors, resulting in a third, combination color.

15 Claims, 3 Drawing Sheets

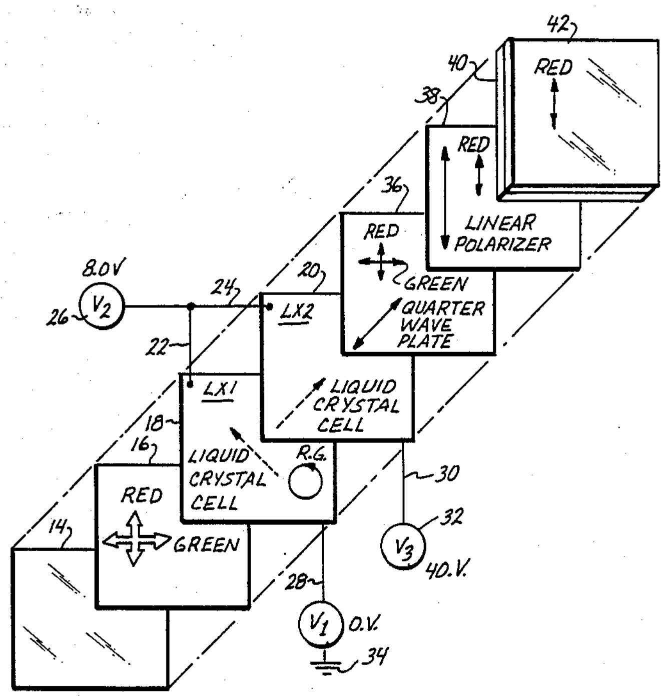


FIG. 1

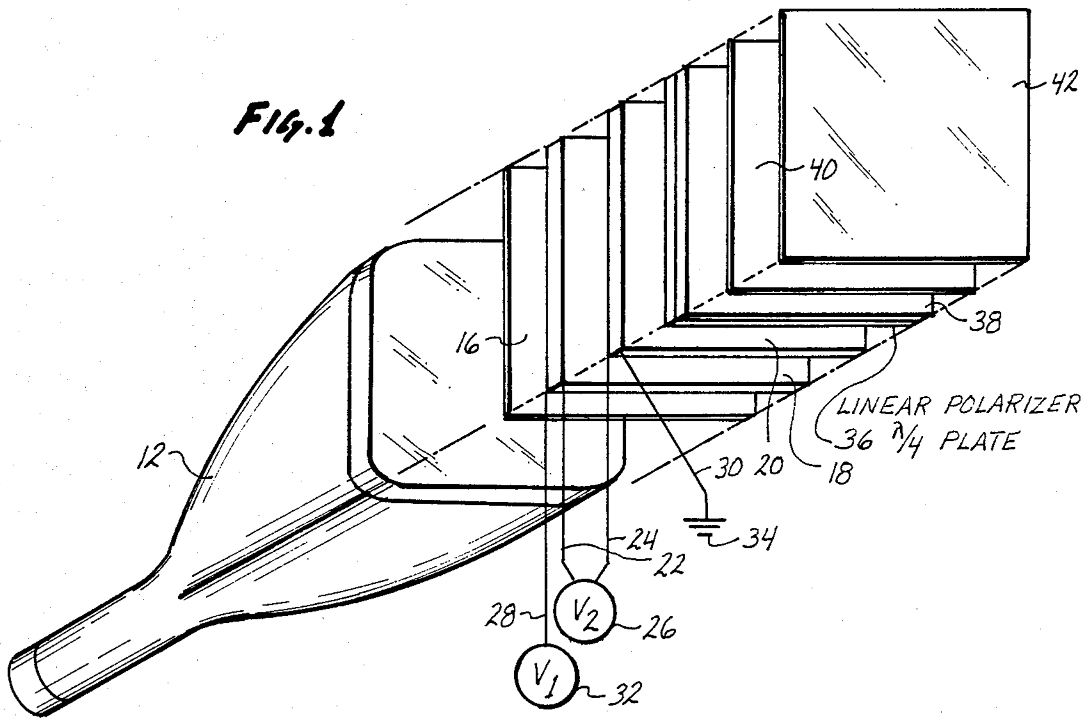

42
40
16
38
LINEAR POLARIZER
36 λ/4 PLATE
12
30 20
18
24
22
34
28
V2
26
V1
32

FIG. 4

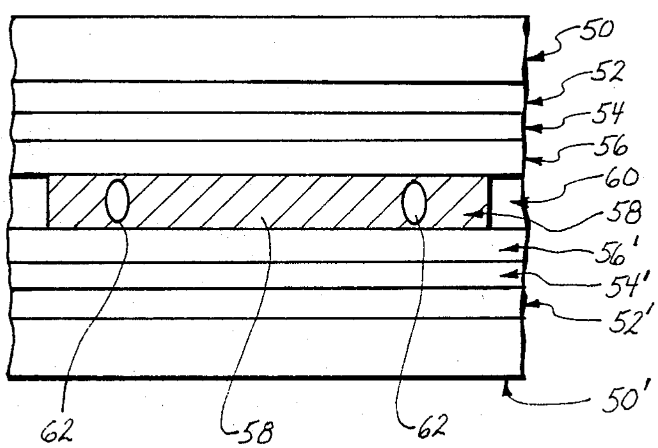

50
52
54
56
60
58
56'
54'
52'
50'
62
58
62

Fig. 2a

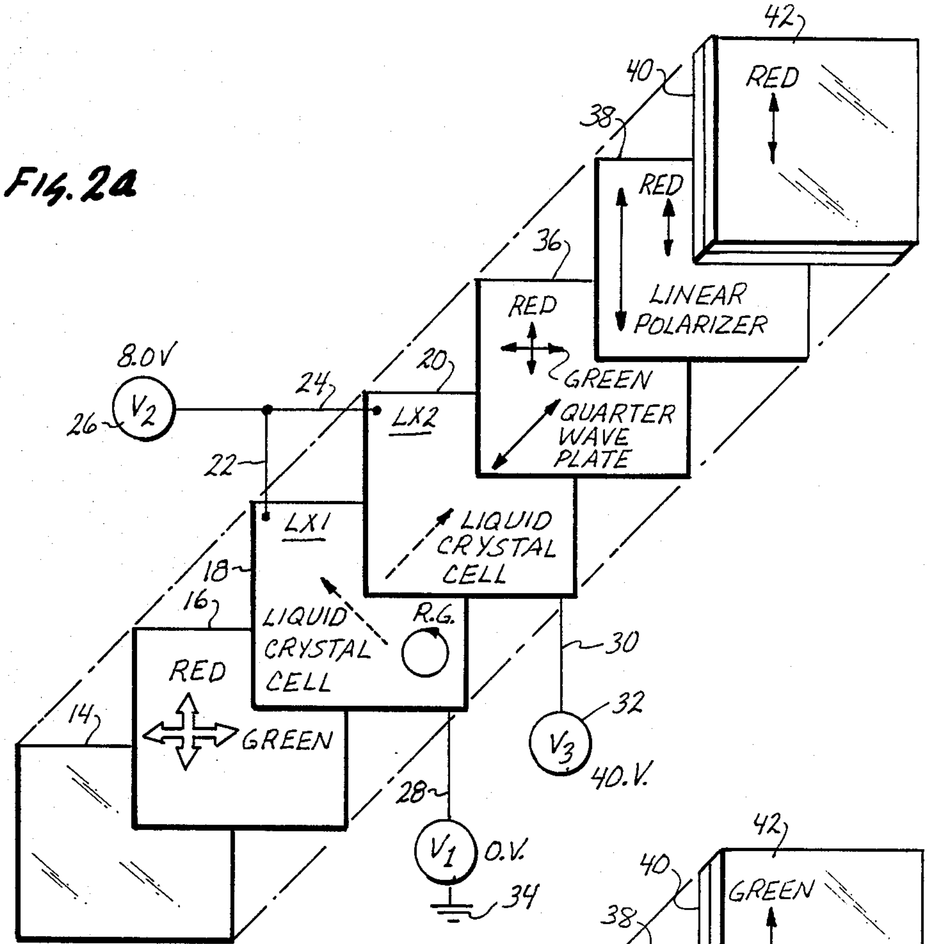
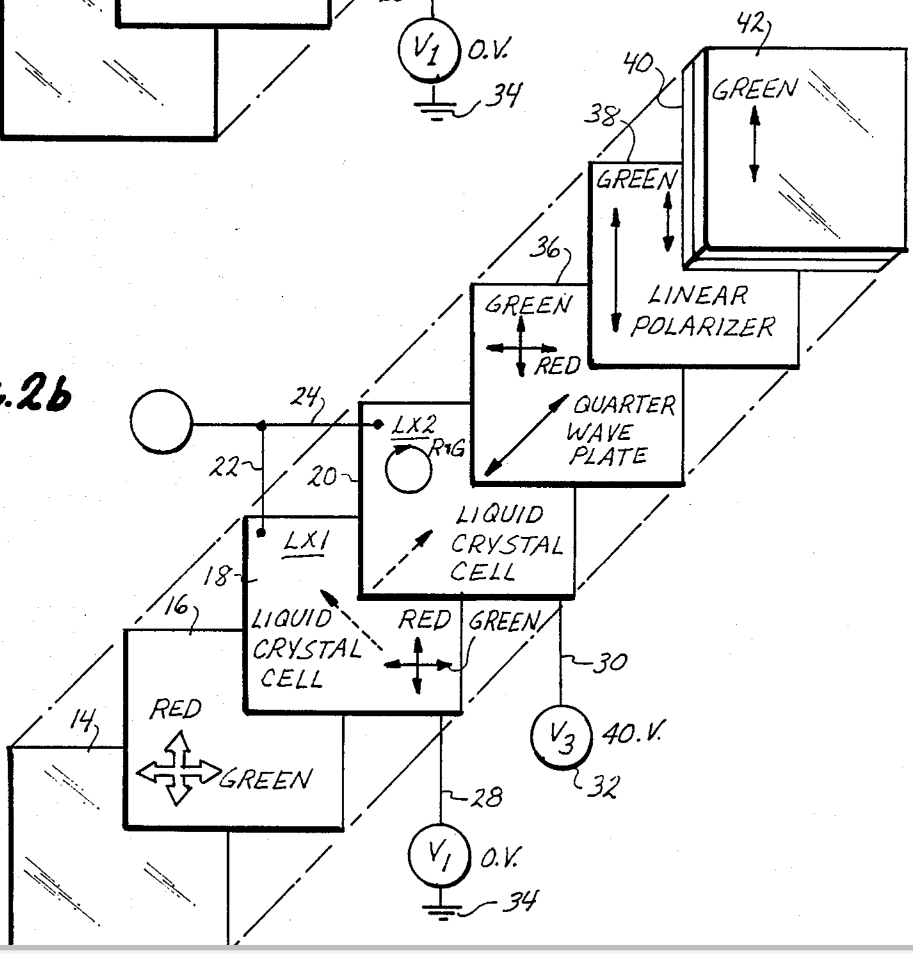

42
40
38
RED
RED
LINEAR POLARIZER
36
RED
GREEN
QUARTER WAVE PLATE
8.0V
V2
26
24
20
LX2
22
LIQUID CRYSTAL CELL
LX1
18
16
LIQUID CRYSTAL CELL
R.G.
RED
GREEN
14
30
32
V3
40.V.
28
V1
O.V.
34

Fig. 2b


42
40
GREEN
38
GREEN
LINEAR POLARIZER
36
GREEN
RED
QUARTER WAVE PLATE
24
LX2
R.G
22
20
LIQUID CRYSTAL CELL
LX1
18
16
LIQUID CRYSTAL CELL
RED
GREEN
30
V3
40.V.
32
14
RED
GREEN
28
V1
O.V.
34

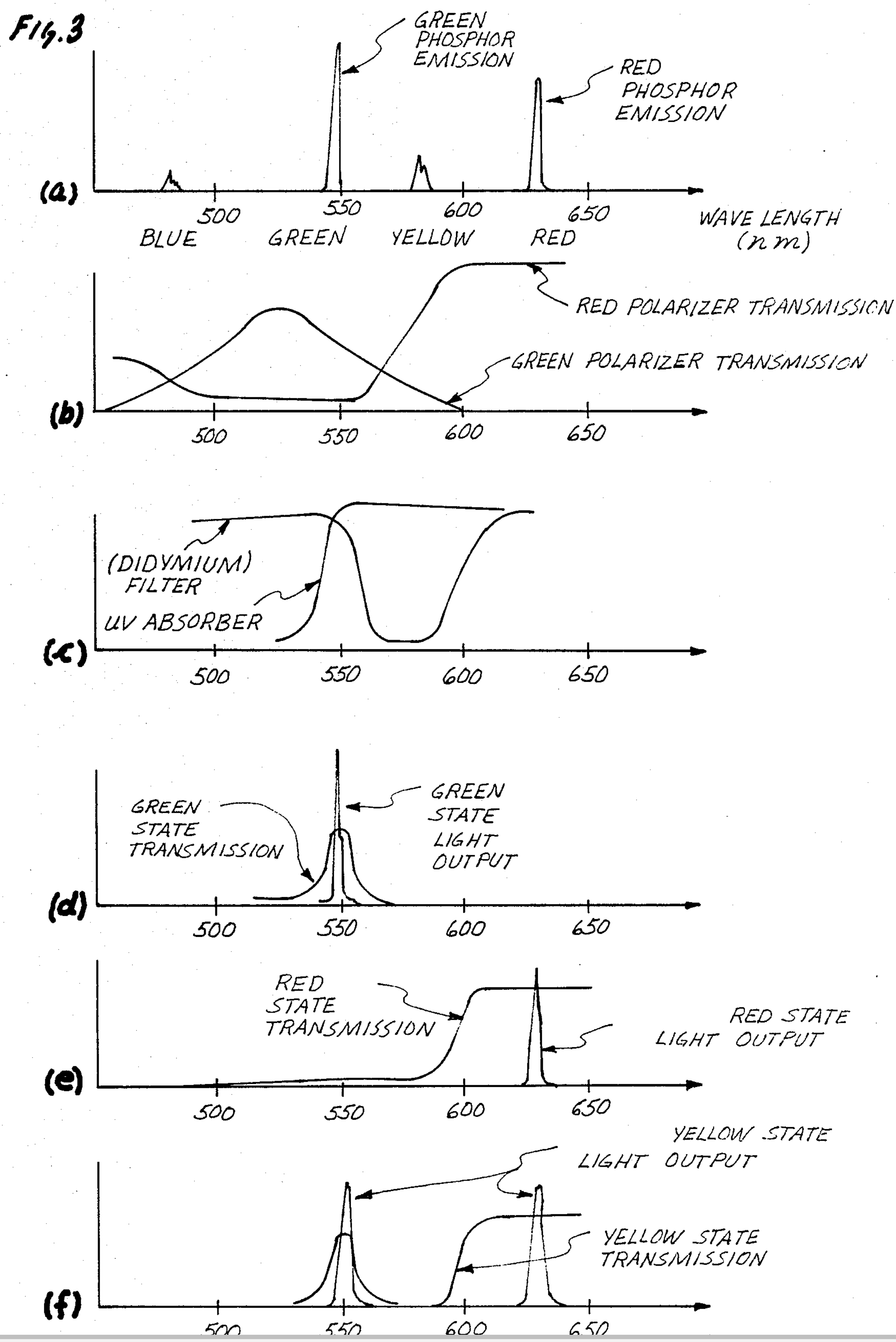


Fig. 3
(a)
GREEN PHOSPHOR EMISSION
RED PHOSPHOR EMISSION
500
550
600
650
BLUE
GREEN
YELLOW
RED
WAVE LENGTH (nm)
(b)
RED POLARIZER TRANSMISSION
GREEN POLARIZER TRANSMISSION
500
550
600
650
(c)
(DIDYMIUM) FILTER
UV ABSORBER
500
550
600
650
(d)
GREEN STATE TRANSMISSION
GREEN STATE LIGHT OUTPUT
500
550
600
650
(e)
RED STATE TRANSMISSION
RED STATE LIGHT OUTPUT
500
550
600
650
(f)
YELLOW STATE LIGHT OUTPUT
YELLOW STATE TRANSMISSION
500
550
600
650

METHOD AND APPARATUS FOR MULTI COLOR DISPLAY

The present invention relates to a method and apparatus for producing multi color displays and, more particularly, to a liquid crystal cell combination which acts as an optical switch to display selected colors from an apparently monochromatic source.

It is well known in the prior art that an apparently monochromatic source such as a cathode ray tube (CRT) can provide a multi color display. From the earliest experiments in color television which used a rotating color wheel together with a CRT, it was possible to place images on the screen in synchronism with the color wheel so that a number of colors could be visualized. This phenomenon was as much a product of the persistence of the image in the human eye as the synchronization of certain images to the concurrent presentation of a filter of preselected color.

The development of the shadow mask tube and the use of triads of monochromatic phosphors was deemed preferable to the electromechanical color wheel and, as a result, the color television industry abandoned the electromechanical approach. It has been taught in the past that a polychromatic source which appears to be monochromatic (from the mixing of the colors) can provide images in the principal colors or in colors which result from the mixture of the principal colors.

PRIOR ART

An early approach to an electronic field sequential color television system was described in the patent to Ernstoff et al U.S. Pat. No. 3,781,465, which issued Dec. 25, 1973. That patent showed a monochromatic CRT with a tri-color liquid crystal assembly that included red, blue and green cells. Electronic circuitry switches the three cells sequentially to provide a series of single color images in rapid succession that, to the eye of the human observer, appear to be in full color.

A different approach was described by Hilsum et al in U.S. Pat. No. 4,003,081, issued Jan. 11, 1977. Their approach, which is the precursor to the approach of the present invention, was to select a CRT that produced an image in at least two colors combined with an electrically controlled filter element. The filter was a liquid crystal material capable of transmitting separately different colors depending upon the applied energizing signals. In a preferred embodiment, video images from a first source, such as radar, were to appear in one color while video images from a second source, such as a computer, were presented in a second color. Alternative embodiments included a field sequential color display which includes a third filter so that a three color combination is available.

The patent to Fergason, U.S. Pat. No. 4,385,806, which issued May 31, 1983, taught a liquid crystal device light shutter in combination retardation with retarding wave plates to compensate for the retardation in the device operating under a bias. Utilizing a bias, the operation of the shutter devices could be speeded up and the retardation plates compensated for the normal birefringence of the cells.

In a continuation-in-part of Fergason, U.S. Pat. No. 4,436,376, issued Mar. 13, 1984, a pair of liquid crystal cells were operated in the manner of a push-pull amplifier in that each cell was operated to impart its own phase shift to a passing optical beam. The application of a bias to the cells aligns the preponderence of the crystals except for the layers immediately adjacent the electrodes. The application of incremental electrical signals across the conducting surfaces achieves a rapid on-off cycle for the cell. The cells thus taught were utilized as a communications link and information was modulated on a light beam by means of applied electrical signals to the cells. Signals that were 180° out of phase were applied to the two cells for push-pull operation.

The general idea of using a "black and white" CRT in conjunction with liquid crystal cells and color polarizers was described by Brinson et al in IBM Technical Disclosure Bulletin Vol. 22, No. 5 of October, 1979. Because a full three color capability is desired, a first liquid crystal cell is followed by a first color polarizer and a second liquid crystal cell is followed by a second color polarizer. Essentially "white" light is transmitted through a linear polarizer and, depending upon the state of the first cell, either cyan or red is passed to the second cell. Depending on the state of this cell, either blue or yellow is passed. The net output of the combination is then either blue, red, green, or black at any instant of time. During a presentation, the net colors would be "mixed" by having images persist through more than one output color phase to provide a substantially full palette of colors.

A slightly different approach was disclosed by Shanks et al in U.S. Pat. No. 4,328,493, issued May 4, 1983. A CRT which emits at least two different colors is combined with first and second color selective polarizers, a liquid crystal cell and a neutral linear polarizer. The liquid crystal cell in one condition rotates the plane of applied polarized light and in a second condition transmits the light without rotation. The cell is then switched in synchronism with the presentation of the images that are to be seen in color. Because the cells cannot be switched between states in the time available during television transmissions, only one half of the cell is switched at a time and the electrodes are driven accordingly.

In the recently published U.K. patent application of Bos et al No. GB 2 139 778 A, published Nov. 14, 1984, corresponding to a U.S. application, Ser. No. 493,106, filed May 9, 1983, now U.S. Pat. No. 4,582,396, issued Apr. 15, 1986, a field sequential color system disclosed a liquid crystal cell which functioned as a variable optical retarder in a polarizing system which included pleochroic filters which selectively transmit a first or a second color, depending upon the polarization of the light. A color sensitive polarizing means is placed in front of a CRT which is capable of emitting light of at least two colors. A first absorption axis passes linearly polarized light of the first color and a second absorption axis passes linearly polarized light of the second color. The liquid crystal cell is followed by a linear polarizer.

When the liquid crystal cell is driven by a first signal, it provides a half wave retardation to applied light. When driven by a second signal, substantially no retardation is experienced by the impinging light. With substantially no retardation of light, only light of one of the colors can pass through the linear polarizer. With half wave retardation, only light of the other of the colors can pass through the polarizer.

A specially designed liquid crystal cell functions as the variable retarder. A nematic liquid crystal cell is designed to be disclination-free and to switch in a "bounce-free" manner as it is switched between two

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