

[54] **DIFFRACTIVE LIGHT MODULATOR**

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 Colo.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 578,647, Sep. 7, 1990, Pat. No. 5,182,665.

[51] **Int. Cl.⁶** **G02F 1/13**

[52] **U.S. Cl.** **359/95; 359/73; 359/53; 359/76; 359/78; 359/100**

[58] **Field of Search** **359/53, 70, 73, 359/75, 89, 94, 95, 100**

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,824,002	7/1974	Beard .	
3,843,231	10/1974	Borel et al. .	
3,909,114	9/1975	Haas et al. .	
4,045,124	8/1977	Pollack et al. .	
4,367,924	1/1983	Clark et al. .	
4,435,047	3/1984	Ferguson .	
4,556,289	12/1985	Ferguson .	
4,563,059	1/1986	Clark et al. .	
4,579,423	4/1986	Ferguson .	
4,596,445	6/1986	Ferguson .	
4,606,611	8/1986	Ferguson .	
4,639,091	1/1987	Huignard et al. .	
4,813,767	3/1989	Clark et al. .	
4,813,771	3/1989	Handschy et al. .	
4,840,463	6/1989	Clark et al. .	
4,850,681	7/1989	Yamanobe et al. .	
4,867,539	9/1989	Goodby et al. .	
4,974,941	12/1990	Gibbons et al. .	
5,013,141	5/1991	Sakata .	
5,182,665	1/1993	O'Callaghan et al.	359/95

OTHER PUBLICATIONS

Jones et al., "Shedding light on alignment," Nature vol. 351, May 2, 1991, p. 15.

Patel et al., "Electrically controlled polarization-independent liquid-crystal Fresnel Lens arrays," Optics Letters vol. 16, No. 7, Apr. 7, 1991, pp. 532-534.

Wayne M. Gibbons et al., "Surface-mediated alignment of nematic liquid crystals with polarized laser light," Nature, vol. 351, May 2, 1991, pp. 49-50.

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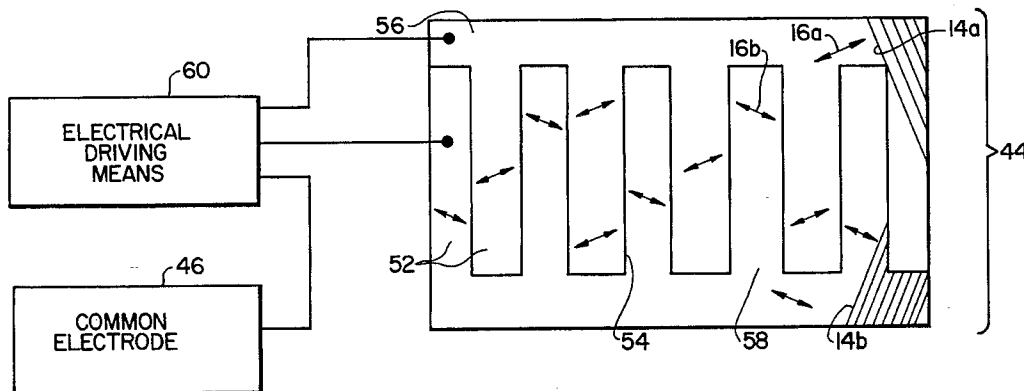
Assistant Examiner—Tan Ho

Attorney, Agent, or Firm—Cushman Darby & Cushman

[57] **ABSTRACT**

An arrangement (apparatus and method) for selectively modulating incident unpolarized light passing through a birefringent material, such as ferroelectric crystal. The apparatus includes a plate having one or more birefringent layers corresponding to first and second alignment regions. The birefringent layer corresponding to the first alignment region has a first optic axis selectably set in a first orientation and a second orientation. The birefringent layer corresponding to the second alignment region has a second optic axis selectably set in a third orientation and a fourth orientation. A switching means controls the optical axis states of the birefringent material by applying switching voltages to the areas of the birefringent layer. Light having passed through the birefringent layer at locations having the first orientation has a different phase from, and same polarization as, light having passed through locations with the third orientation, independent of a polarization state of the incident light. As a result, the birefringent material has a uniform state at locations where the corresponding optic axes between the first and second alignment regions are parallel, and a diffracting state produced by an interaction between the light having passed through areas having the first orientation and the light having passed through areas having the second orientation. The arrangement is effective for reflective modulators, multilayer modulators or polarization-preserving modulators, and has applications for intensity modulation, blurring modulation and beam steering.

30 Claims, 14 Drawing Sheets



OTHER PUBLICATIONS

- Williams G, et al, "Electrically controllable Liquid Crystal Fresnel Lens, " Proceedings of SPIE, vol. 1168, No. 352-357, et al., Current Developments in Optical Engineering and Commercial Optics, Aug. 1989.
- Mochizuki et al, "Elimination of Crosstalk in Highly Multiplexed STN-LCDs by Using Conducting Orientation Films", SID 90 Digest, pp. 84-87.
- Rieker, T. P. et al., "Layer and Director Structure in Surface Stabilized Ferroelectric Liquid Crystal Cells with Non-planar Boundary Conditions, " vol. 6, No. 5, 1989, pp. 565-576.
- Nakaya et al, "Electrooptic Bistability of a Ferroelectric Liquid Crystal Device Prepared Using Charge-Transfer Complex-doped Polyimide-Orientation Films" Japanese Journal of Appl. Phys., vol. 28, No. 1, Jan. 1989, pp. L116-18.
- Channin et al, "Rapid Turn Off in Triode Optical Gate Liquid Crystal Devices," Applied Physics Letters, vol. 28, No. 6, Mar. 15, 1976, pp.300-302.
- Wu et al, "Physical Properties of Diphenyldiacetylenic Liquid Crystals, " J. Appl. Phys., 65(11), Jun. 11, 1989, pp. 4372-4376.
- Patel et al, "Alignment of Liquid Crystals Which Exhibit Cholesteric to Smectic C* Phase Transitions," J. Appl. Phys. 59(7), Apr. 1,1986, pp. 2355-2360.
- Armitage et al., k "Liquid-Crystal Differentiating Spatial Light Modulator," Proceedings of SPIE, vol. 613, Nonlinear Optics and Applications, Jan. 1986, pp. 165-171.
- Cotts et al, "Appendix F: Compilation of Polymer Conductivity Data," Electrically Conductive Organic Polymers for Advanced Applications, 1986, pp. 176-202.
- Doane, J. W. et al, "Polymer Dispersed Liquid Crystals for Display Application " , Molecular Crystals and Liquid Crystals, vol. 165, 1988 pp. 511-532.
- Cognard, Jacques, "Alignment of Nematic Liquid Crystals and Their Mixtures " , Molecular Crystals and Liquid Crystals, Supplement Series, 1982, pp. 64-68.
- Mao, C. C. et al., "Low Power, High Speed Optical Phase Conjugation Using Chiral Smectic Optically Addressed Spatial Light Modulators," Optic News, vol. 15, Sep. 1989, pp. A-38, Abst. TuA4.

FIG. 1A
(PRIOR ART)

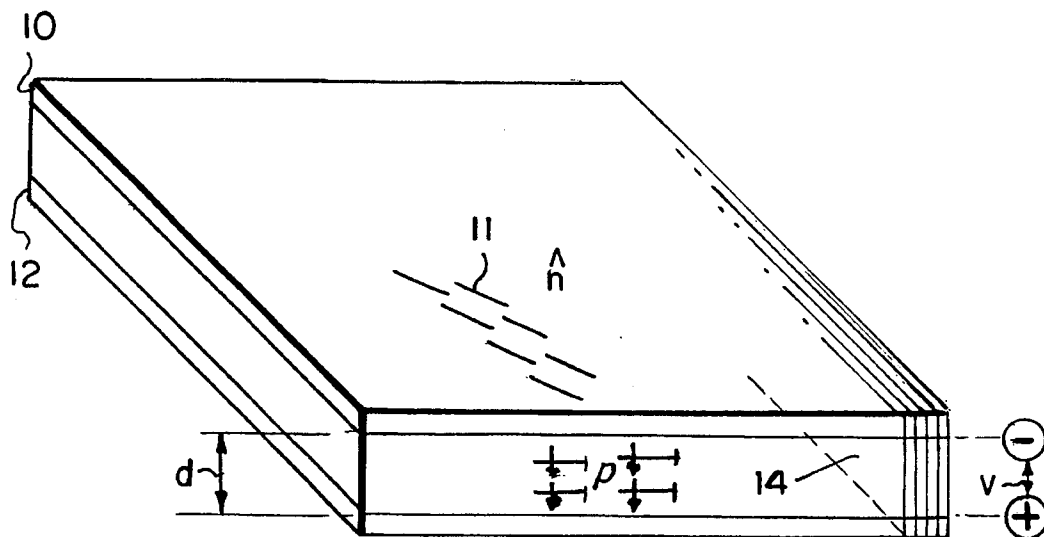


FIG. 1B
(PRIOR ART)

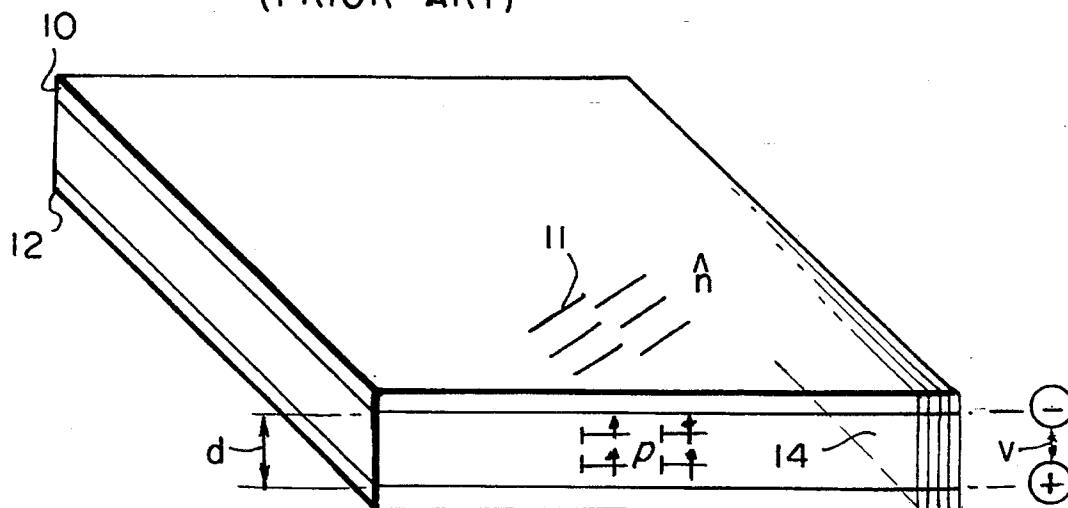


FIG. 2

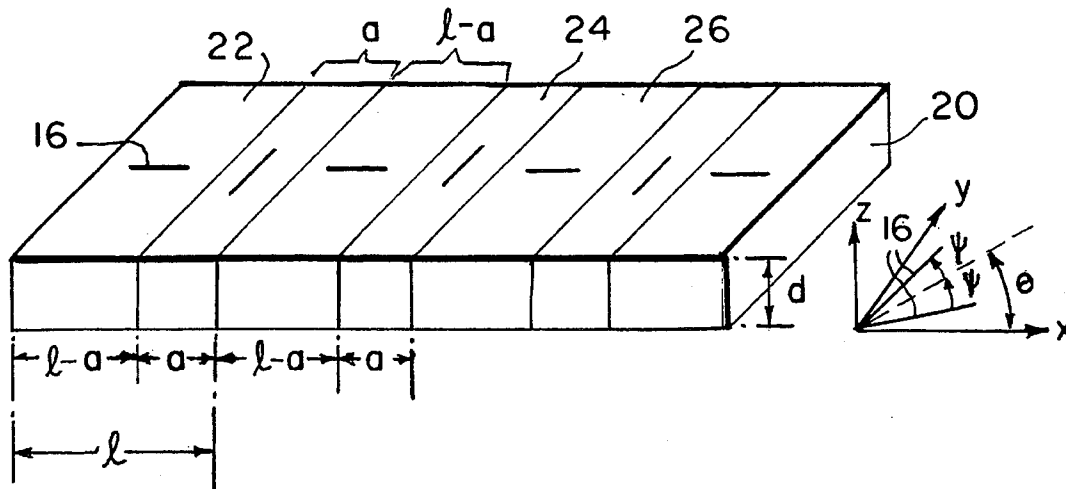
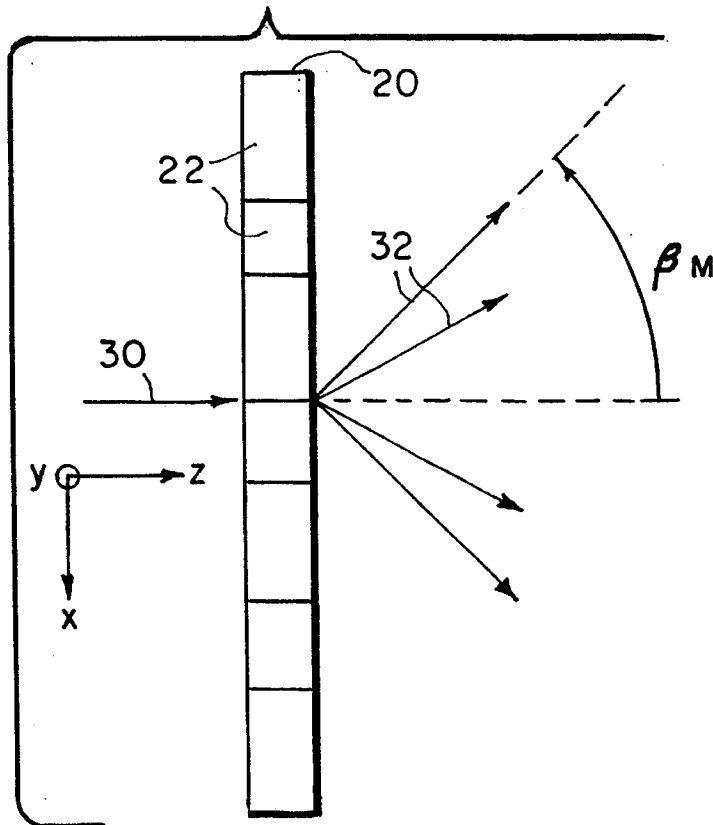


FIG. 3



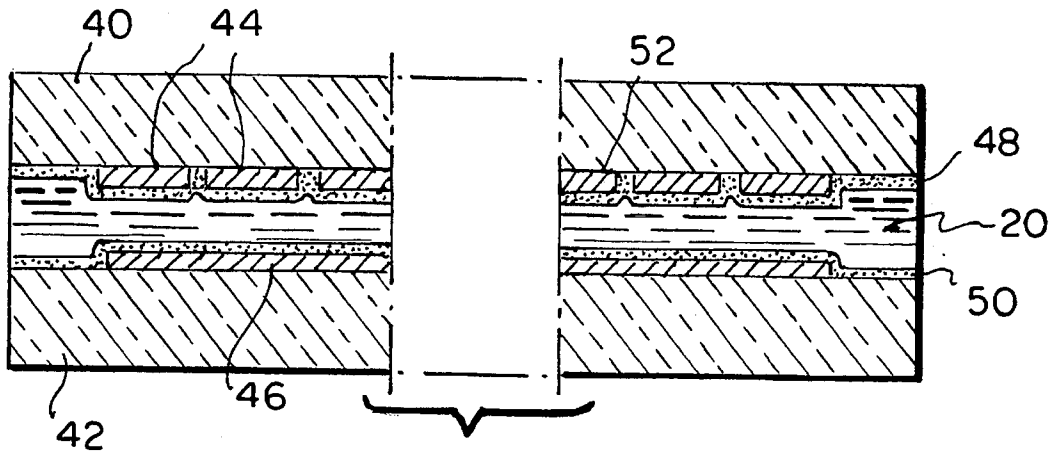


FIG. 4

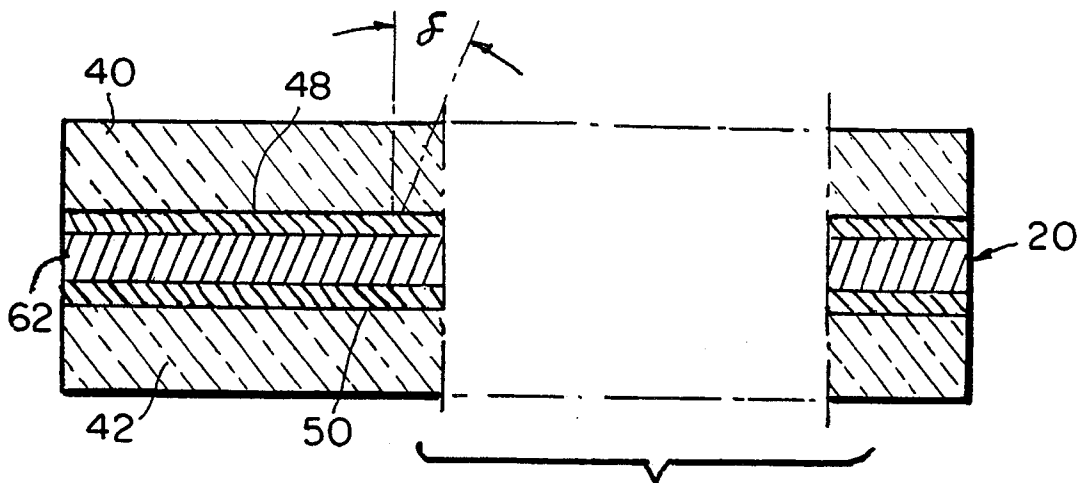


FIG. 6

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