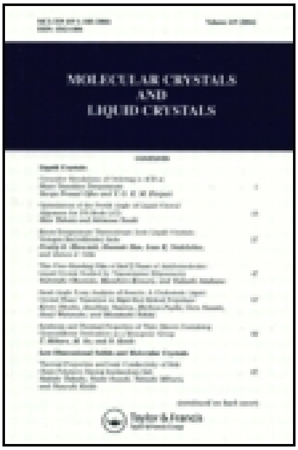

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Ferroelectric Liquid Crystal Cells with High Birefringence Optical Fibers for Polarization-Based Optical Logic

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FERROELECTRIC LIQUID CRYSTAL CELLS WITH HIGH BIREFRINGENCE OPTICAL FIBERS FOR POLARIZATION-BASED OPTICAL LOGIC.

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Abstract The ferroelectric SSFLC display was coupled with two optical fibers to arrange a simple logic network. In the arrangement a binary polarization-mode operation was examined.

INTRODUCTION

Since early serious investigations of liquid crystals electrooptical properties the workers have made inquiries about ferroelectricity in those liquids[1,2]. However almost 20 years of search in the field had passed until the first truly liquid ferroelectric material was found and examined[3]. Then the material again waited some years to be applied utilizing its unusual properties. The LC ferroelectrics joint in a unique way electrical, optical, and surface properties, so that transmitted light can be affected by low energy expense to the extend not achieved in other materials. The first realization of SSFLC optical switch showed many advantages not possessed by earlier inventions based either on LC devices or classical light modulators as well. The ferroelectric SSFLC device can be driven by low voltage, low energy signals of submicrosecond speed to perform in a simple arrangement the bistable, programmable half-wave plate function. The advantages of the SSFLC device predestinate it for optical logic.

Although there are many inventions realizing the Boolean funtions by use of halfwave switch, some of them very sophisticated, the construction of extended optical computing systems need to solve also the problem of interconnection network. This could be done by using optical fibers. We have taken an attempt to link the SSFLC-cell with the light fibers.

EXPERIMENTAL

The SSFLC-built-in optical unit can perform all binary logic funtions by operating with two intensity levels or two orthogonal polarization states of transmitted light[4]. The second, unabsorptive operation mode seems to utilize better the physical properties of SSFLC and does not loss any entrance light energy. We have examined the both logic implementations in an experimental arrangement shown in figure 1. The He-Ne laser beam (λ = 633 nm) was linearly polarized by polarizer (P) and a halfwave plate (λ/2) was used to easy control of polarization plane. Next the laser beam was coupled utilizing a lens (L) into single mode fiber (SMF) which preserved the polarization. Single mode preserving polarization fibers are highly birefringent and

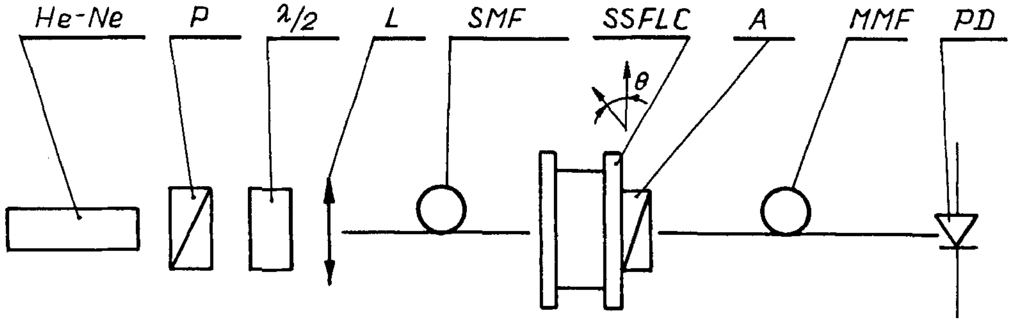

FIGURE 1 The vertically polarized incident light passes through the gate unaffected if the voltage on the LC layer forces its optic axis to be parallel to the electric vector of incident beam and is rotated orthogonally for the voltage of opposite sign (see text).

therefore they possess two stable polarizations axes: fast and slow (fig.2). When polarized light is injected into highly birefringent fiber with the plane of polarization parallel to one of fiber stable axes it propagates for long distance without coupling to the

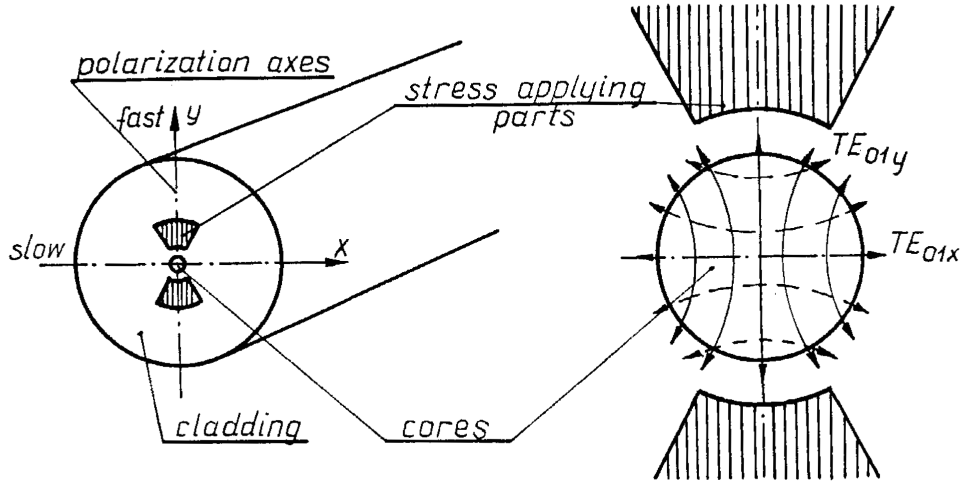

FIGURE 2 Crossection of high birefringent optical fiber

orthogonal eigenmode. Polarization maintaining fiber helps to eliminate the influence of external parameters in unstable environments and to diminish the light spot just in front of SSFLC cell. In our experiments the York HB 600 fiber with phase retardation $3.7 \cdot 10^3$ rd/m at 633 nm was used. Light was launched parallel to one principal axis of the fiber. The SSFLC cell could change the plane of polarization by 90° according to the applied voltage and an analyzer (A) transferred the polarization modulation into intensity modulation. Then the multimode fiber (MMF) transmitted the intensity-modulated light to the detector. The SSFLC element was a typical sandwich cell of about 3 μm thick filled with room temperature ferroelectric smectic C* mixture, aligned by polyimide coating in order to obtain inside the cell a "bookshelf" geometry. The cell works exactly as a controllable halfwave plate only for the light of a vacuum wavelength λ = $2d \cdot \Delta n$, where d is being LC layer thickness and Δn is a birefringence of LC. The cell operates with maximum contrast if the switching angle θ, being a material property, is equal to 22.5°. For LC used θ was 25°, so the optical axis of the LC layer is switched over about 50°, which negatively affects the contrast of the device. We have measured the value of contrast C and the dynamics for the fibers-gate arrangement, shown in fig.1, using photodiode (PD). As receiving fiber an ordinary multimode fiber (MMF) of 50 μm - core diameter was used. The contrast C of the SSFLC display alone, taken as the maximum to minimum output light intensities for one of two orthogonal polarization states not not exeed 50. This is rather low value, due to insufficient fitting of d and θ to their theoretical values. After placing the SSFLC between the fibers the total signal detected droped by 36 dB from its direct-coupled value and the contrast decreased to 1/3 of that for SSFLC itself. The appreciable decrease of a total signal is apparently due to the energy losses of diverging light cone caused by unavoided increase of the distance between emitting and receiving fiber surfaces and the reflections from additional interfaces of the SSFLC cell. Some basic improvements of the coupling parts of the setup should boost the output signal. The switching speed measured as the rise time t_r of an optic pulse from 0.1 to 0.9 of its maximal hight by rectangular driving voltage is shown in fig.3 as a function of the voltage. The dynamics of the SSFLC examined was of the order of miliseconds at room temperature. The reaction times of the SSFLC are determined mainly by magnitude of spontaneous polarization P_s and viscosity v, so by LC material constants. For our LC ferroelectric we have obtained P_s = 1.2+0.1 nC/cm^2 and then the evaluation gives the viscosity v=56 cP, which is rather typical value for room temperature material. Therefore the slow response of our SSFLC cell is a result of low spontaneous polarization of the mixture used.

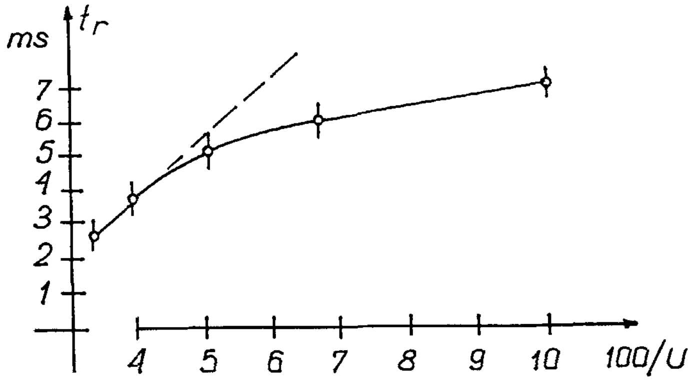

FIGURE 3 Optical response rise time t_r of the logic arrangement versus applied voltage U.

SUMMARY

We have carried out an experimental attempt to combine the SSFLC optical gate and fiber waveguides in a simple optical path. We have obtained two-states operation of the arrangement, but we have observed significant decrease of the total signal and of the contrast. We have realized some problems which have to be solved:

- efficient coupling at the optical fiber-SSFLC plane
- careful adjustment of the fibers polarization planes
- minimizing the distance between input and output fibers.

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