2 × 2 OPTICAL FIBRE POLARISATION SWITCH AND POLARISATION CONTROLLER

Indexing terms: Optical fibres, Polarisation, Optical switching, Liquid crystals

A liquid crystal based optical fibre polarisation switch is demonstrated. Switching voltages of about 3 V were used and switching speeds of a few Hz obtained. In addition, the device may be used as the basis for a polarisation controller in coherent optical detection schemes.

Suitably aligned liquid crystals may be used to control the polarisation state of light passing through them. In particular, the twist cell (commonly used in display devices) may rotate plane polarised light by 90°. However, when a suitable voltage is applied across such a cell, the twist effect is lost and rotation no longer takes place. Here, this effect is used to perform switching between the two axes of a piece of high-birefringence (hi-bi) bow-tie fibre. Previously this type of switching has only been demonstrated in bulk devices.[1,2]

Use of the twist effect in a device configuration offers many useful features:

(i) the low switching voltages (a few volts) are IC compatible

(ii) low power consumption, typically sub-microwatt

(iii) the small interaction length of light with the liquid crystal should result in low losses

(iv) the twist effect is largely independent of temperature over a substantial temperature range

(v) the effect is independent of wavelength in the visible and IR region.

Features (iii)–(v) do not apply to the liquid crystal clad type device.[3] Further, for clad devices the cell thickness is of critical importance, this is not so for the twist cell. The beam deflection device,[4] whilst offering most of the features of the twist effect switch, is not an in-line device.

The hi-bi fibre has a fast and a slow axis, as depicted in Fig. 1. A liquid crystal cell is formed directly between the ends of two pieces of the fibre, thus producing an in-line device. With suitable treatment of the fibre end face, the director of the liquid crystal is made to align parallel to the fast axis. One fibre is then rotated by 90° with respect to the other. This surface alignment configuration thus causes the liquid crystal to take upt a twist ~~cell structure~~. [redacted] and thus emerges on the slow axis of the output fibre, Fig. 1*a*. Similarlarly, light input on the fast axis, emerges on the fast axis of the output. Applying a voltage across the cell destroys ~~its twist nature. The director in the bulk of the liquid crystal~~ becomes aligned parallel to the propagation direction, and thus has no effect on the polarisation of the incoming light. This means that light input on the slow axis, emerges on the fast axis (Fig. 1*b*) and vice-versa.

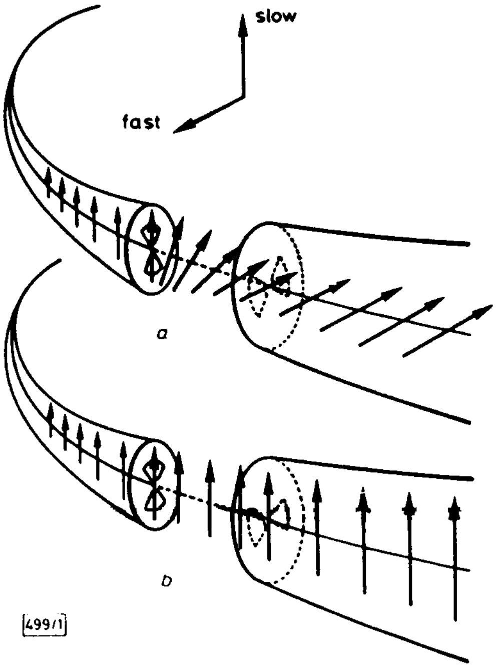

Fig. 1 *Action of liquid crystal cell on light travelling along fibre*
a Switch is 'off', rotation of polarisation takes place
b Switch is 'on', no rotation occurs

Two pieces of the same hi-bi fibre (NA = 0·15, cutoff = 506 nm) were cleaved to provide flat ends. The ends were then coated with 60 nm of indium-tin-oxide (ITO) to provide optically transparent electrodes. The sides of the fibre adjoining the ITO coated ends were then coated with 60 nm of gold, thus providing electrical contact to the ends. With these electrodes in place the ends were further coated with SiO_x, by evaporation at an oblique angle (60° to the fibre axis) to provide an aligning layer[5] for the liquid crystal, alignment being perpendicular to the fast axis of the fibre. Both fibre ends were mounted on 3-axis stages and their separation adjusted to about 30 microns, their fast axes were arranged to be orthogonal.

Light from a He–Ne laser (633 nm) was launched, via a film polariser, along the fast axis of the input fibre (Fig. 2). The position of the ends was adjusted to achieve maximum coupling (for the 30 micron separation) and the intensity of light on both axes of the output fibre measured, giving a crosstalk of −20 dB and an insertion loss estimated[6] at 1 dB. The liquid crystal (E7-BD) was then introduced, via capillary action, between the fibre ends. No noticeable increase in insertion loss was found.

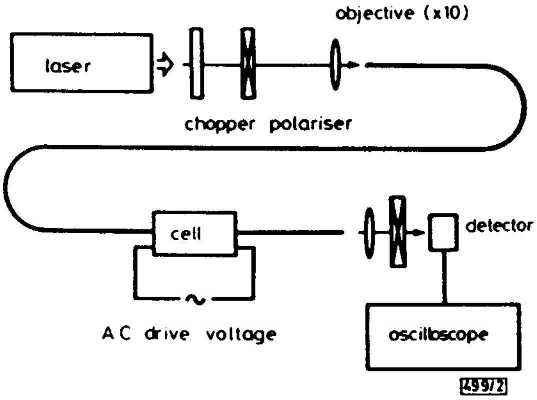

Fig. 2 *Experimental arrangement used to analyse operation of liquid crystal cell*

The intensity of light on the two axes of the output fibre was monitored using a second polariser (Fig. 2). An AC voltage at 8 kHz was applied to the cell, and the output on each axis monitored, as the amplitude of the AC signal was increased. The resulting switching behaviour is shown in Fig. 3. It is anticipated that the crosstalk could be improved by optimising the orientation of the two fibre ends,[1] one with respect to the other. Note the low voltages required for the operation of the switch.

Modulation of the driving voltage with a square wave of lower frequency allows the switching times to be investigated. Data for this are presented in Fig. 4. The modulation frequency was 4 Hz and the resulting rise and decay times are 50 and 100 ms, respectively (similar to those of Reference 2). This indicates that the device may operate up to ~10 Hz. Reducing the fibre separation should reduce the switching time and reduce the insertion loss.

In addition to its action as a polarisation switch, an inline liquid crystal cell may be used to form the basis of a polarisation controller.[7] In this application, standard single mode fibre is used and the liquid crystal cell is formed with no twist (the aligning layers are parallel to each other). Application of a voltage now adjusts the degree of birefringence, so that the cell now acts as a variable birefringent plate. The work reported here demonstrates that such a device can be built inline without the need for bulk optics.

Summarising then, an in-line 2 × 2 optical switch has been demonstrated having a crosstalk of approximately −20dB and an insertion loss of 1 dB. Switching times in the order of 10 Hz were obtained, higher speeds are possible, but they lead to an increase in crosstalk. Further, potential application of the device with regard to coherent detection has been discussed.

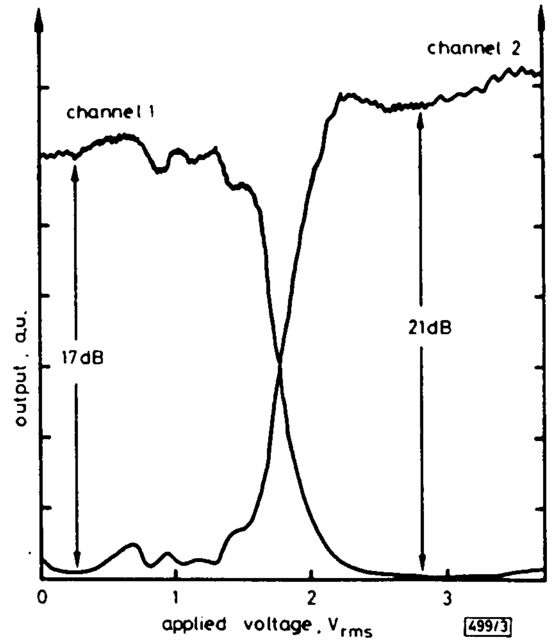

Fig. 3 *Switching behaviour*

As voltage is increased, light is transferred from one axis (channel 1) to the other (channel 2)

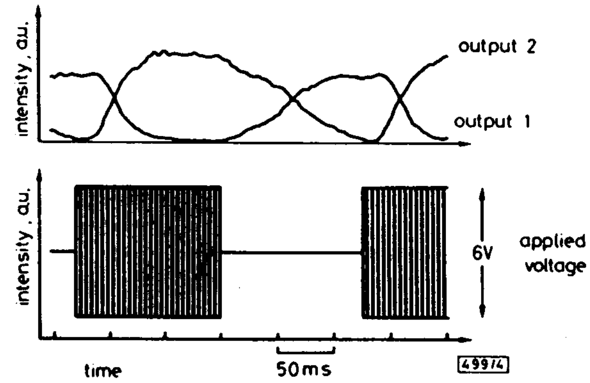

Fig. 4 *By applying modulated AC voltage (bottom trace) switching operation is observed (top trace)*

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