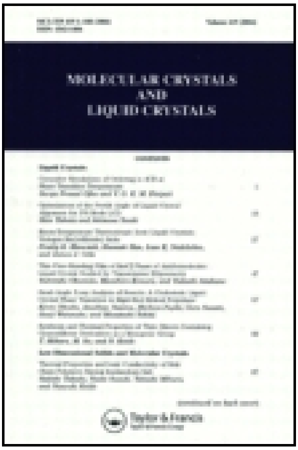

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# Transmission Modification of Optical Fiber Components Intensity by using Liquid Crystals

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# Transmission Modification of Optical Fiber Components Intensity by using Liquid Crystals

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The alignment and electrical reorientation of a liquid crystal around a tapered fiber were studied in order to improve the efficiency of optical components using liquid crystal. The method is based on the visualisation of the taper losses occuring when immersed in a liquid crystal of indices higher than silica. The polarisation into the taper was also determined.

*Keywords:* optical fibers; tapers; Fredeericks effect

## INTRODUCTION

The development of optical communications since 15 years have led to the conception of optical components in order to increase the capacity of fibers to drive always more data at very high speed and on a long distance. Future needs concern in particular external switches of the signal propagating in the fiber. Indeed, up to now, only a few components have been proposed to allow an external modulation of the signal. One method for producing this type of component is given by the combined use of a liquid crystal around a tapered fiber. A tapered fiber is a well known optical component which allows the spreading of the core-field in the cladding and then the sensitivity to the external medium[1]. The liquid crystal reorientation by optical Fredeericksz effect around a taper inducing a modification of the external index, a modulation of the power transmitted can be obtained. This yielded to the conception of components based on the association of a taper with a nematic liquid crystal confined between two metallised plates. The first study proposed by Veilleux[2] has demonstrated the possibility of the liquid crystal action on a taper. We propose here to perform this work by investigating the alignment and the reorientation of the liquid crystal near the taper and by determining the polarisation into the taper. These two studies are of first interest to improve the efficiency of the component.

## THEORY

The reducing of the fiber diameter induces an expansion of the signal propagating in the core-fiber into the cladding and a coupling to different cladding modes. The slope of the decreasing diameter determines the nature of the taper. When the slope is very slow, the taper is called adiabatic: this notation was introduced by Snyder[3] to notify that the losses induced by the diameter decreasing is weak compared to the energy propagated. The adiabaticity criterion can be expressed as:

$$\rho \, d\rho / dz \ll z_b \qquad (1)$$

where $\rho$ designs the local fiber diameter and $z_b$ is the beat length between the two first modes of the local multimode fiber. When (1) is fullfilled, the intrinsic losses of the taper are weak and the coupling occurs mainly to the $HE_{11}$ cladding mode (no coupling to the higher cladding modes). The propagation in the uniform reduced diameter is then assumed by only one mode leading to an

## EXPERIMENTAL SETUP

The tapers were produced with a fusion splicer: the fiber is maintained between two clamps which are connected to motors in the splicer. To realize a taper, the fiber is pulled with the same strength in the opposite directions by the two motors while an arc fusion heats it. The fusion splicer used (FSU Erickson) allows to change the following parameters: intensity of the arc current (10 to 20 mA), time of draw (0.1 to 10 s) and draw length (0 to 999 μm). To optimize the sensitivity to the external medium, a long and thin taper was necessary (diameter reduced part more than 1 mm long, less than 30 μm of thickness). This was achieved by repeating the tapering process several times (typically 10) and each time slowly changing the position of the fiber in the splicer machine. The fiber used was a standard single-mode fiber at 515 nm with an external diameter of 125 μm and a core-diameter of 3 μm. By adjusting the different parameters of the splicer machine, it was possible to perform tapers weak non-adiabatic as shown in the Figure 2.

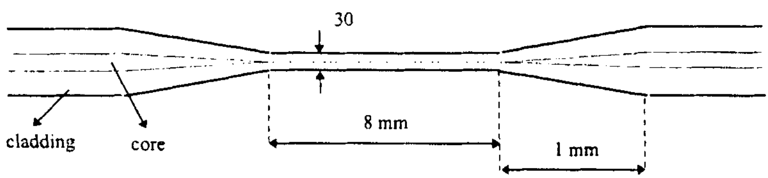


FIGURE 2 Tapered fiber parameter

The transmission of the fiber was measured by the use of a He-Ne laser emitting at 633 nm and a power meter. The liquid crystal was confined in a cell delimited by two glass plates recovered by an ITO coating allowing the application of an electric field to the cell. We used classical fibers to play the rule of spacers (125 μm of thickness). To achieve a good reorientation by

Fredeericksz effect, it was necessary to apply a 1 kHz a.c. voltage with an amplitude of 200 V. The plates were treated with diamond paste in order to obtain a planar alignment without any electric field.

## RESULTS

### Polarisation in the Taper

The propagation being assumed by several cladding modes in our case (taper slowly non-adiabatic), the theoretical analysis doesn't allow to determine it. We have so experimentally determined the polarisation into the taper by cutting it in its reduced diameter part. A polarizer was inserted between the He-Ne laser and the fiber and an analyzer was placed after the cleaved taper. The fiber was kept straight right to avoid depolarisation due to stresses or curves of the fiber[5]. The length of the fiber before the taper was minimized about 30 cm, avoiding any depolarisation due to the intrinsic fiber birefringence. The study was made with different liquids of index comprised between the air and silica. The results showed a conservation of the polarisation whatever the index concerned, the ratio of polarisation increasing when the liquid index approach silica one. We can so consider that a taper doesn't modify the incident polarisation. The use of liquid crystal can then be optimized by adjusting the incident polarisation in function of its alignment.

### Alignment and Reorientation of the LC

#### Principle of the method

The experimental investigation of the liquid crystal alignment and reorientation is based on an optical method. The idea is to visualize the taper refraction losses in the liquid crystal and to deduce informations about the quality of the liquid crystal orientation near the taper. The refraction losses occuring when the liquid crystal is of both indices higher than silica, this method is available only with a « classical » liquid crystal ($n_o$ , $n_e$ > $n_{sil}$ ). The presence of a surrounding medium of index higher than silica doesn't allow the guided propagation in the taper, but one can still observe the beat phenomenon[6]. This causes the light to be periodically concentrated near the periphery of the taper (beating due principally to the two first cladding modes).

The refraction losses will then be caracterized by conical pencils of light escaping periodically from the taper at the angle given by the Fresnel law. Considering that the cladding modes propagate parallel to the taper axis[7], we can write:

$$n_{sil} = n_{cl} \sin \theta \qquad (2)$$

where $n_{sil}$ and $n_{cl}$ design respectively the indices of silica (1.458) and liquid crystal, and $\theta$ represents the angle of the pencils with the taper axis. The optical determination of $\theta$ allows to characterize the liquid crystal orientation by using a liquid crystal of known indices.

**Results obtained**

The experiments were achieved with the nematic ZLI 1083 LC (Merck) which ordinary and extraordinary indices are respectively $n_o$ = 1.48 and $n_e$ = 1.6. All the experiments were realized with a polarisation linear at the beginning of the taper . The first experiment was with the polarisation parallel to the plates. The visualization of the taper losses showed the existence of pencils with the same angle along the taper, before applying the electric field, i.e. $\theta$ = 10 °. This probes an homogeneous alignment just around the taper. The calculation of the index seen by the selected polarisation gives us the value n = 1.48. We can then say that the observed alignment seems to be planar. When the liquid crystal is electrically reoriented, no change occured in the pencils angle indicating that the index is the same. The reorientation is then efficient around the taper. The recording of the transmitted intensity through the taper indicated no variation ( in concordance with the conservation of the losses angle). The second experiment was led with the incident polarisation perpendicular to the plates. In this configuration (cf. Theory), the effect of the liquid crystal is expected to be maximum. The visualization of the losses without electric field showed exactly the same results that for the first configuration (same uniform angle along the taper). We can conclude that the planar alignment is efficient just around the taper. When the electric field was applied, the situation was very different. The angle of the losses pencils changed indeed, indicating that the selected polarisation didn't see the same index. The value of the angle was about 24 °. The use of (2) gave us the local index about 1.6 for the concerned polarisation. This means that the liquid crystal is well homeotropically oriented around the taper (cf. Figure 1). The recording of the transmitted intensity through the taper (Figure 3) showed a variation about 20 %.

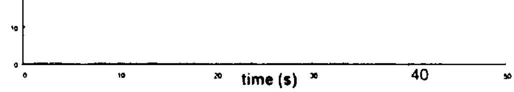


FIGURE 1 Transmission modification of the fiber when an AC field is applied

## CONCLUSION

The alignment and reorientation of a liquid crystal around a tapered fiber were studied by an the visualization of the refracted losses. It was shown in particular that a planar alignment is efficient a few microns around the taper. These improvements are important for the realization of any optical component based on the active operation of a liquid crystal around a fiber.

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