Direct optical observation of disclination effects in active photonic devices

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1. Introduction

Liquid crystals (LC) are increasingly finding uses in fields outside of display optics. Their strong electro-optic response can be used in applications such as tunable photonic devices, for example, to make tunable planar Bragg gratings. While Bragg gratings are well known as fixed wavelength reflectors, the application of a liquid crystal can convert these fixed reflectors into tunable filter elements, with potential applications in telecommunications networks [1].

We have previously demonstrated such devices, and have shown the capability to tune the Bragg peak through adjacent DWDM channels [2]. These devices contained channel waveguides and gratings defined by laser writing techniques. The Bragg peak is tuned by applying an electric field across the device, which causes a change in the LC refractive index, which modifies the modal index of an exposed Bragg grating. The tuning curves for these devices exhibit hysteresis depending on whether the field amplitude is being increased or decreased. In this work we report investigation of the liquid crystal behaviour by direct observation of polarization state and physical changes in the LC. We will also highlight new interaction geometries and show that careful control of modal interactions can be used to optimize the available tuning performance.

2. Results and discussion

Our previous laser-written LC tunable devices used silica-on-silicon substrates. To analyze the LC alignment processes occurring we fabricated physically and electrically equivalent structures, but which were optically transparent allowing direct observation (Fig.1). A straight ~50µm wide gap was scribed into the ITO to form two parallel electrodes. The ITO was coated with surfactant for homeotropic alignment and Merck nematic LC 18523 was applied to the cell. Transmission microscopy experiments were performed through crossed polarizers and the resultant polarization changes inside the LC cell recorded.

Our observations suggest that the hysteretic behaviour seen in our previous work [3] can be linked to the disclination dynamics of the LC. The shape of the defect is governed by the geometry of the electrodes. As the disclination line forms above our waveguides, any change in LC index due to director realignment will manifest itself as a change in centre wavelength. The transparent LC cells showed areas of undefined director between the electrodes that narrowed and subsequently formed a disclination at higher voltages. Figure 2 shows that the disclination retreats at higher fields when the LC becomes fully-aligned with the applied field. The critical voltage values from the transparent cells agree with tuning curve threshold points.

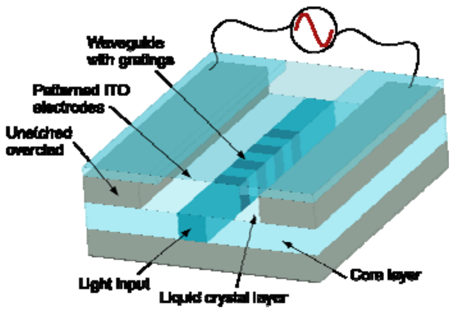

Fig. 1. Cell geometry for liquid crystal tunable Bragg grating devices

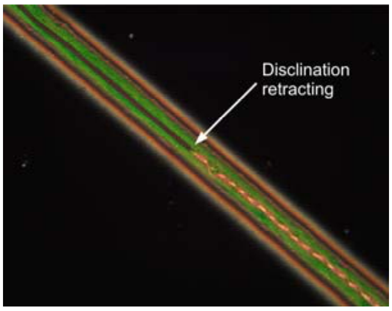

Fig. 2. Disclination line dynamics seen via crossed polarizers when ramping an a.c. voltage up.

The tuning previously noted exhibits hysteresis but is linear at higher voltages. It can therefore be assumed that the ratio of disclination to regions of well defined director varies with voltage. Indeed, point defects have been seen along the line defect [2]. These form nucleation points from which the disclination can retreat. Thus the percentage of the waveguide covered by disclination decreases with increasing voltage, and so the change in effective index is not a linear function of applied voltage.

We aim to investigate whether disclination dynamics can be controlled by the application of periodic defects along the electrode region. This potentially allows for faster disclination retraction, aiding tuning speed and response characteristics of the tuning devices.

3. Conclusions

We have previously demonstrated electro-optical tuning of a planar Bragg grating device using a LC overlay. The tuning curves exhibit hysteresis which is the result of disclination dynamics in the electrode region of our devices. We have presented new results on high resolution optical observation of disclination dynamics. These results, together with similar measurements in vertical cell arrangements, support the relationship between disclination formation and the observed hysteresis in spectral tuning.

4. References

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