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Towards High-Speed Liquid Crystal Electrically Tunable Planar Bragg Gratings For Integrated Optical Networks

Benjamin D. Snow[a], F. R. Mahamd Adikan[a], Andriy Dyadyusha[b], James C. Gates[a],
Huw E. Major[a], Corin B. E. Gawith[a], Malgosia Kaczmarek[b], Peter G. R. Smith[a]

a) Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ.
b) School of Physics and Astronomy, University of Southampton, Southampton, SO17 1BJ.

Liquid crystal-based integrated optical devices offer the potential for high speed and dynamically tunable optical switches in modern telecommunications networks. Here, electrically tunable devices have major advantages over their thermal counterparts, with superior response times and low operating voltages (~100V). Our approach to achieving such devices is to fabricate planar optical waveguides with integrated Bragg gratings via direct UV writing[1] into silica-on-silicon samples with evanescent field coupling into a liquid crystal overlay through an etched window (Fig. 1(a)). Such electrically tunable devices work on the principle of shifting the Bragg wavelength by modifying the effective index of a waveguide in a multilayer substrate. Electrically controlled liquid crystal birefringence modifies the waveguide effective index, producing a Bragg wavelength shift. In our early samples, Merck 18523 nematic liquid crystal is used as it has a compatible refractive index to silica (n_o=1.44, n_e=1.49 at λ=1550nm). Homeotropic alignment of the liquid crystal is provided by application of a surfactant layer.

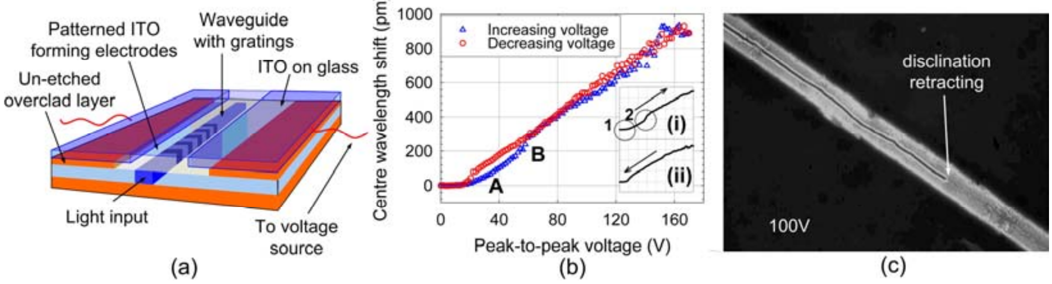

Fig. 1 (a) Schematic diagram of liquid crystal Bragg grating configuration; (b) Tuning curve with insets showing the threshold points; (c) Disclination line seen via cross-polarized microscope.

During operation as a tunable grating, the grating spectrum and the centre wavelength shift were recorded for each voltage condition. Fig. 1(b) shows the tuning curve of the device, exhibiting 932.7pm Bragg wavelength shift at 170Vpp (114GHz at λ=1561.8nm). Interestingly, the curve displays hysteresis between points A and B (Fig. 1(b)) where the insets show the tuning curve with increasing (i) and decreasing (ii) voltage. It was observed that the curves for increasing voltage exhibit two distinct points where the tuning gradient increases significantly (circled). We believe that the lower threshold is where the electric field is large enough to overcome interactions of liquid crystal molecules with surface and elastic forces. The origin of the higher threshold is likely to be due to the multi-domain structure of liquid crystals created in the etched window and their interactions with applied field, creating disclination lines[2] along a particular axis (Fig. 1(c)). Here we will discuss how modification of line defects affects the switching time between optical wavelengths, and how this can be applied to the design of high-speed optical network components.

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[1] Cladis, P. E.; van Saarloos, W.; Finn, P. L.; Kortan, A. R. *Phys. Rev. Lett.*, **1987**, 58, p. 222-225.

[2] Sparrow, I. J. G.; Emmerson, G. D.; Gawith, C. B. E.; Smith, P. G. R.; Kaczmarek, M.; Dyadyusha, A. *Appl. Phys. B*, **2005**, 81, p. 1-4.