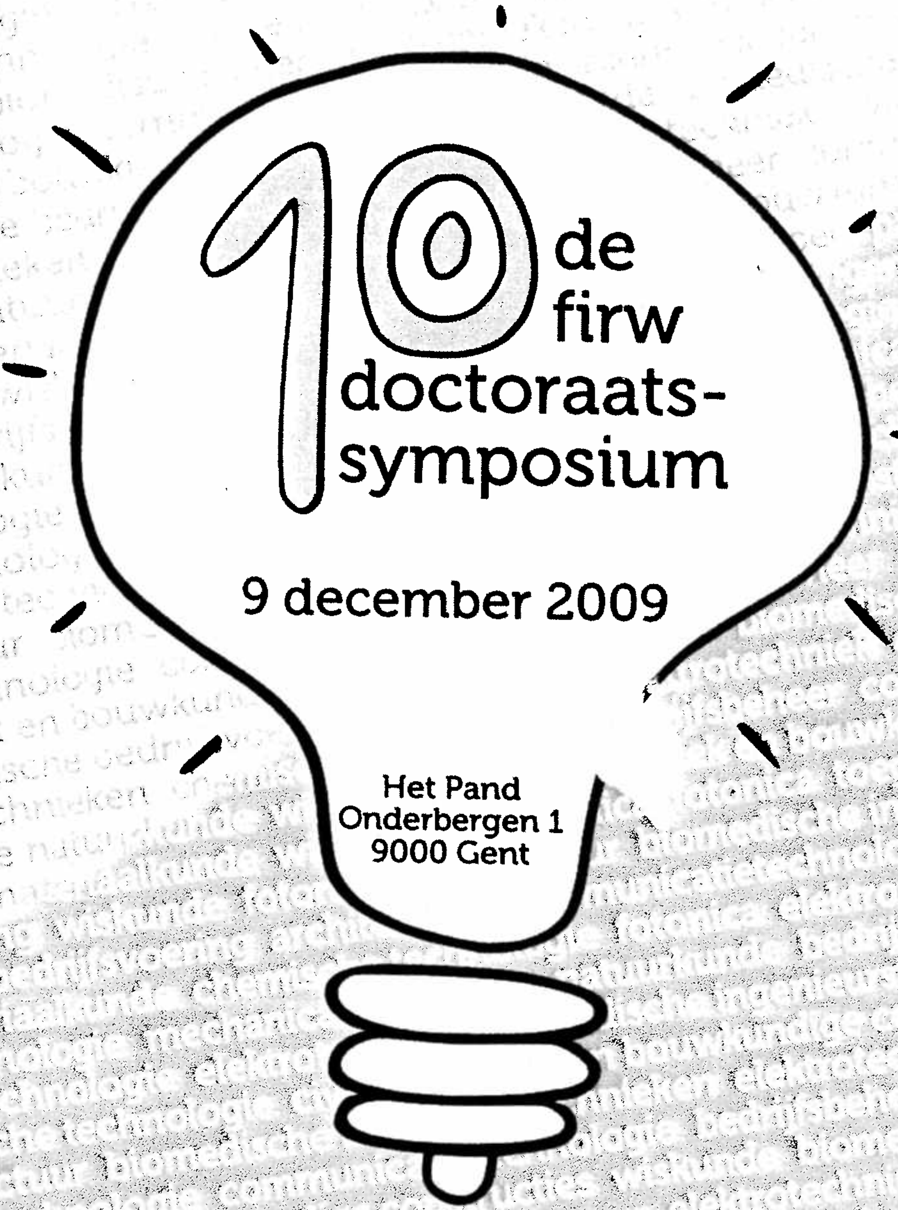

10de firw doctoraats-symposium

9 december 2009

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Tuning Optical Ring Resonators with Liquid Crystals

Wout De Cort

Supervisor(s): Roel Baets, Kristiaan Neyts

I. Introduction

Communication through optical networks requires components that can filter out specific wavelengths from a broad spectrum. Ring resonators are excellent components for this task. When such a micrometer-sized ring is close to an optical waveguide it diverts certain wavelengths -depending on the ring's size and materials used- from a broadband signal to the output ('drop') waveguide (see Figure 1). Ring resonators are already being used as basic components in (de-)multiplexers for optical networks. In reconfigurable networks the filtering of wavelengths needs to be adjustable and the ring resonators need to be tunable. This can be achieved by e.g. heating or cooling, by carrier injection or, as will be shown in this article, by applying liquid crystals as a top layer on the chip.

II. Tuning Mechanism

Light can travel and e.g. take bends in waveguides because it is trapped -or confined- by the high refractive index of the waveguide core. This, however, does not mean that there is no light outside the core. Light travelling in waveguides on the surface of optical chips, penetrates to a certain extent the regions around the waveguide. Therefore, a material applied as a cladding layer, will interact with the light in the waveguide. When identical optical filters are clad with different materials,

W. De Cort is with the Department of Information Technology and the Department of Electronics and Information Systems, Ghent University (UGent), Gent, Belgium. E-mail: wout.decort@ugent.be .

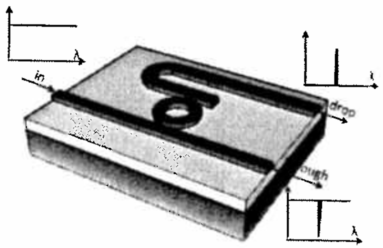

Figure 1. Optical ring resonator as used in this work. Schematic views of the spectra at input, drop and through port are given.

they will filter different wavelengths depending on the refractive index of the materials.

We will use a liquid crystal as a cladding layer. A liquid crystal consists typically of rod-shaped molecules and its refractive index is anisotropic. This means that light travelling in different directions through the liquid crystal will see different refractive indices. When an electric field is present, the molecules will reorient themselves along the fieldlines. This effect is very useful when the liquid crystal is applied as a cladding on waveguides. Depending on the presence and direction of an electric field the light in the waveguide will see a different refractive index in the cladding. This gives us the possibility to tune the filter characteristics of optical ring resonators with an externally applied electric field.

III. Our Devices

The ring resonators are fabricated at IMEC in the Silicon-On-Insulator material system. In this high index-contrast the light can take sharp bends, resulting in ring resonators of only a few micrometers diameter [1]. The many years of experience with silicon-based CMOS components allow mass fabrication of photonic integrated circuits as the same facilities can be used.

Glue mixed with spacers is used to attach a glass plate on the chip. This glass plate is covered with two additional layers. The ITO layer will serve as a top contact necessary to apply the electric field. The alignment layer determines the orientation of the liquid crystal at the surface of the glass layer. Finally the cell is filled with the liquid crystal by capillary forces. Figure 2 shows a schematic cross section of the cell.

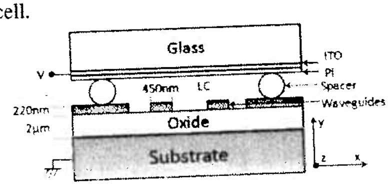

Figure 2. Schematic cross section of our cells.

On the surface of the chip, the molecules align themselves parallel to the surface and to the ribs of intersecting surfaces. When a voltage is applied between the ITO layer and the chip itself, the liquid crystal will align parallel to the fieldlines, perpendicular to the surface.

IV. Results

We fabricate the devices described above in our clean room facilities. The optical characterization is done by sending light vertically into the waveguides through grating couplers. The working principle of grating couplers is based on diffraction of light and their use makes it easy to align optical fibers to the nanophotonic waveguides [2]. We measure the output spectrum of the ring resonators for different values of the applied voltage. We are able to track the change of one of the filtered wavelengths. The curve can be seen in Figure 3. We get a shift of about 0.6 nm, which is better than the values found in literature [3]. We see that there is a certain voltage required for the tuning to start. This is the treshold-voltage at which the elastic forces holding the molecules are overcome. At higher voltages we see a saturation effect, meaning that the molecules have turned to a completely vertical orientation. In the inset of Figure 3 the output spectra for 0V and 30V can be seen. As we are measuring the output of the 'through' waveguide we see dips in the spectrum at the location of the filtered wavelengths.

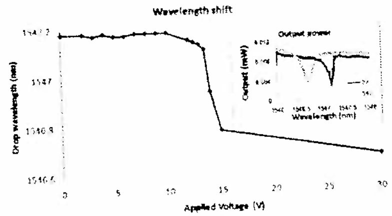

Figure 3. Drop wavelength as a function of applied voltage. The inset shows the spectra at 0V and 30V.

V. Conclusions

We have fabricated and measured tunable optical ring resonators based on the electrooptic effect of a liquid crystal cladding layer. We achieve a tuning range of 0.6 nm.

Acknowledgments

The author acknowledges IWT-Vlaanderen for funding this research.

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