Design and realization of an Optical Switch based on Long-Range Surface Plasmon Polaritons and Liquid Crystal

W. De Cort[1,2], H. Desmet[1,2], S Scheerlinck[1], K. Neyts[2], R. Baets[1]

[1] *INTEC Department, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Gent*
[2] *ELIS Department, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Gent*

Introduction

The guiding of light along metal stripes, or other structures, has attracted quite a lot of attention recently. If the metal is thin enough (around 20 nm) a so called Long Range Surface Plasmon Polariton (LR SPP) can be excited. This is an extraordinary electromagnetic (EM) wave that can propagate over a considerable distance on metal surfaces. Researchers have developed components such as power-splitters, interferometers etc. using this principle[1], [2]. In this work, we study the properties of these waves and present the design and development of an optical switch. This switch is based on LR SPP guidance in combination with liquid crystal (LC). This is a component that has, to our knowledge, not been investigated before.

Understanding SPP and LR SPP

LR SPPs are special forms of the surface plasmon polaritons (SPPs). SPPs are electro-magnetic excitations bound to a single interface of a metal and a dielectric. When the thickness of the metal is decreased, the plasmon modes propagating on both sides of the metal will eventually couple to form supermodes. These supermodes exist in two forms. The Long Range (LR) mode is characterized by low losses and a long propagation length whereas the Short Range (SR) mode has high losses and thus a short propagation length. We are interested in the LR mode. The formation of these modes is highly dependent on the symmetry of the structure they are propagating in, ie. whether or not the refractive indices of the dielectrics on both sides of the metal are equal. A representation of this structure as well as the field distribution of the LR SPP is presented in Figure 1.

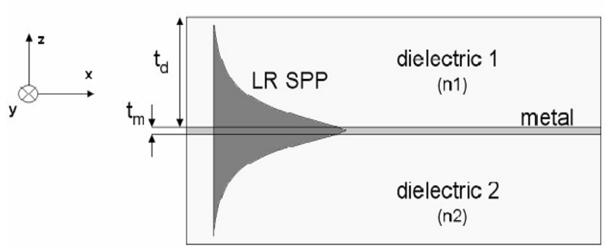

Figure 1: Structure and LR SPP field distribution

Properties of LR SPP

We have simulated structures appropriate for waveguiding LR SPP. Such structures consist of three layers: a dielectric layer (thickness t_d, refractive index n1), a thin layer of metal (usually gold or silver, thickness t_m) and again a dielectric layer (t_d, n2). We are interested in the losses of the LR mode. We alter the parameters of our system (t_m, n1 and n2) and verify their influence on these losses. We choose t_d to be 10 µm and the wavelength λ to be 1550 nm. The influence of t_m (n1 and n2 are kept at 1.55) is studied first. A thickness of 20 nm results in losses as low as 17 dB/cm. We verified this experimentally. The losses increase rapidly with increasing thickness. Next, we study the influence of asymmetry ($n1-n2 \neq 0$). When the difference between n1 and n2 becomes too large, the LR SPP mode will not be supported anymore. By looking at the effective index of the mode, we were able to determine these (theoretical) limits.

Design of the switch and measurments

To realize an optical switch based on LR SPP, we hope to exploit the effects of asymmetry discussed in the previous section. We want to change the refractive index of one of the layers surrounding the metal and use a nematic LC to achieve this. The change in refractive index is realized by changing the temperature in the neighborhood of the isotropic to nematic transition temperature. During this transition, the refractive index of the LC experienced by the LR SPP, changes. At a certain temperature, corresponding with a certain refractive index of the LC, there will be a good match with the refractive index of the dielectric on the other side of the metal and LR SPP guiding will be possible. When the refractive indices are too different, there will not be any guiding.

We realise the switch as follows: on an InP substrate, we spincoat a dielectric layer (SU-8, refractive index 1.575) of 15 to 20 µm thick. Then we evaporate a 20 nm thick gold layer, in which we etch stripes of 8 µm wide, and on top of which another SU-8 layer is deposited. In some regions we etch the top SU-8 layer away so we can drop our LC on top of the gold. We use 5CB (clearing temperature around 35°C) for the LC because of its ability to match the 1.575 refractive index of SU-8. The whole structure is 2 mm long.

The measurments show a peak in the output power when the temperature reaches the clearing temperature of the LC, as expected (Figure 2). However, the output power is quite low, which indicates that the losses are high, probably due to scattering of light.

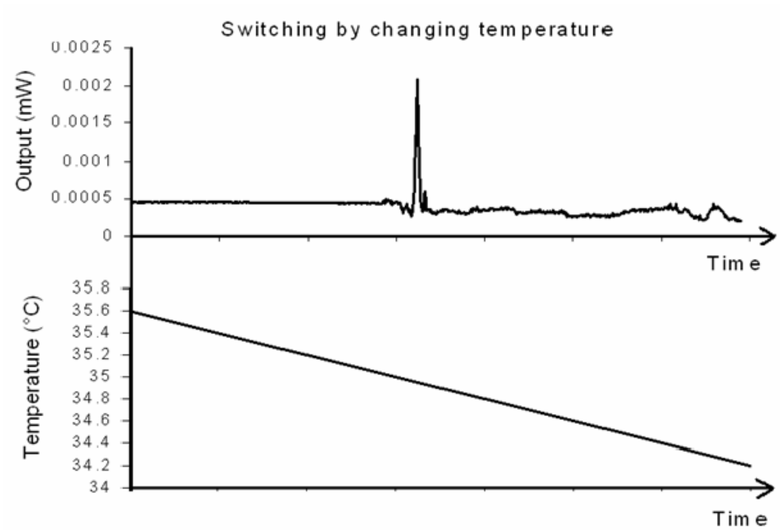

Figure 2: Influence of the temperature on the output power.
Around the clearing temperature, the output peaks

References

[1] Alexandra Boltasseva, *Integrated-optics components utilizing long-range surface plasmon polaritons.* Ph.D. Thesis. 2004

[2] R. Charbonneau, C. Scales, I. Breukelaar, N. Lahoud, G. Mattiussi and P. Berini, *Passive integrated optics elements based on long-range surface plasmon polaritons,* Journal of Lightwave Technology **24**, 477 (2006)