Design and Simulation of All-Polymeric Reconfigurable Optical Node

Anish Dhiman
Electrical and Electronics Engineering Department
Birla Institute of Technology and Science
Pilani, Rajasthan, India
f2012174@pilani.bits-pilani.ac.in

Rahul Singhal
Electrical and Electronics Engineering Department
Birla Institute of Technology and Science
Pilani, Rajasthan, India
rahulsinghal@pilani.bits-pilani.ac.in

***Abstract*—A simulation study of a voltage controlled reconfigurable optical node is presented here. An all-polymeric device structure is assumed and parameters accordingly are used in design simulation. The core material for all-polymeric device is assumed to be Tri-cyanovinylidene-di-phenyl-aminobenzene (TCVDPA) doped SU-8 electro-optic polymer with non-doped SU-8 as under and over-clad. A 1 x 4 optical reconfigurable node is designed and simulated within a voltage limit of ± 50 V assuming Poly(3,4-ethylenedioxythiophene)-Poly(styrene sulfonate) (PEDOT:PSS) electrodes. The voltage applied to electrodes at device junctions configures the splitting ratio while applied at device branches configure the wavelength routing.**

Keywords—reconfigurable optical node; wavelength routing; variable splitting; all-polymer device.

I. Introduction

Reconfigurable optical nodes are subject of interest recently for enabling power efficient long reach passive optical access networks [1-2]. A quasi-passive reconfigurable green node that can perform splitting and wavelength routing functions using micro-electro-mechanical systems (MEMS) based latches and a Mach–Zehnder interferometer (MZI) structure are reported earlier [3-4]. Passive Optical Networks (PONs) may use variable power splitters at remote nodes to provide efficient power budgets. Energy is required when re-configurability is to be achieved. MEMS latches provide energy efficiency in idle states to ensure cost-effective access networks. A low voltage operated all-polymeric device may also be considered as one of the affordable solutions for cost-effective networks..

PEDOT-PSS is one of the promising candidates for electrodes among the most widely employed conductive polymers due to its high conductivity, transparency in visible range and processing flexibilities [5]. The PEDOT:PSS electrodes may be fabricated with SU-8 as the surrounding layers [6]. PEDOT:PSS Electrodes may get deteriorated on application of a potential difference of 50V [7]. SU-8 is a negative tone, near UV resist and is widely used in MEMS based devices. It has excellent optical transparency beyond 400 nm and that makes it a preferred material for the fabrication of polymeric optical devices [8]. The channel core may be formed by doping with TCVDPA or Disperse Red 1(DR1) as it is popularly and commercially known. TCVDPA is a highly stable Nonlinear Optical (NLO) chromophore and direct photo-definition of TCVDPA in SU-8 host was reported earlier by Balakrishnan et.al. [9]. Electro-optically active waveguides may be obtained by direct photo-definition after NLO chromophores are incorporated in a photo-definable polymer.

A simulation study of low voltage (≤ 50 V) controlled MZI structure that achieves both power splitting and wavelength routing is presented in this paper where an all-polymer structure is assumed. Simulation results for variable power splitting for an SU-8/TCVDPA doped SU-8/SU-8 based polymeric device controlled through PEDOT:PSS based electrodes were presented earlier [10]. Here, in this paper, the ability of the MZI structure to provide wavelength routing with variable splitting through change in voltage on electrodes is presented. This paper presents the design and analysis of a reconfigurable optical node that splits the incoming optical power in a ratio determined by applied voltage at the input junction of MZI structure and wavelength routing is obtained by changing the phase by application of voltage at one of the branches of MZI structure. In the next sections, the details of implementation of optical node will be discussed. The design is optimized to obtain de-multiplexing between two wavelengths for demonstration of the voltage effect on branches of MZI.

II. Device Design

The BeamPROP simulation engine, used for design and simulation of device, is a part of the RSoft Photonics Suite, and is based on advanced finite difference beam propagation (BPM) techniques. The simulation engine is fully integrated into the RSoft CAD environment which allows the user to define the material properties and structural geometry of a device. Variable splitting of optical power can be obtained by applying voltage at first y-junction as presented in [10]. A cascaded structure is designed and simulated to investigate the possibility of demultiplexing in the optical signal after a splitting loss. In case, no voltage bias is provided at junction, then an expected 3 dB splitting loss is achieved as shown in Fig. 1. By the principle of Mach-Zender interferometry, light travelling along a path undergoes a phase shift due to the electric field created by application on Voltage V1 to one of the electrodes, when other is grounded as shown in Fig. 1. By controlling V1, the relative phase shift of the two arms can be controlled. If V1 is set such that light has a phase difference of 180°, destructive interference will take place, resulting in no light to be transmitted. If no voltage is applied at V1, phase difference will be of 0°, and the original input signal would be observed at the output. Same holds true for Voltage V2 applied to other branch as shown in Fig. 1.

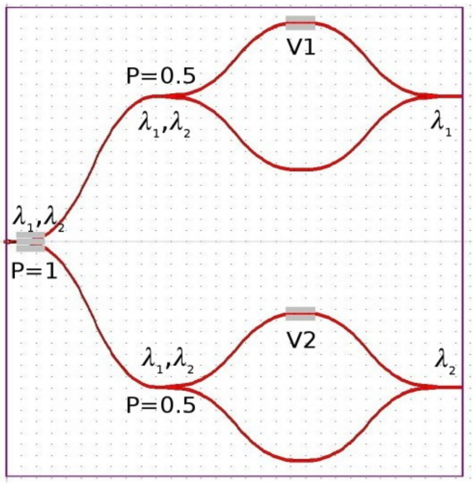

Fig. 1. Schematic design of an active reconfigurable node.

The width of waveguide was set to 2.5 µm so that single mode propagation is allowed. The electrodes are placed on the top of over-clad with 1 µm gap from core to provide maximum transverse electric field effect at core of the device. The device design is optimized with asymmetric lengths of s-bend branches with a longer one with electrode for observing wavelength demultplexing phenomenon.

III. Simulation Results

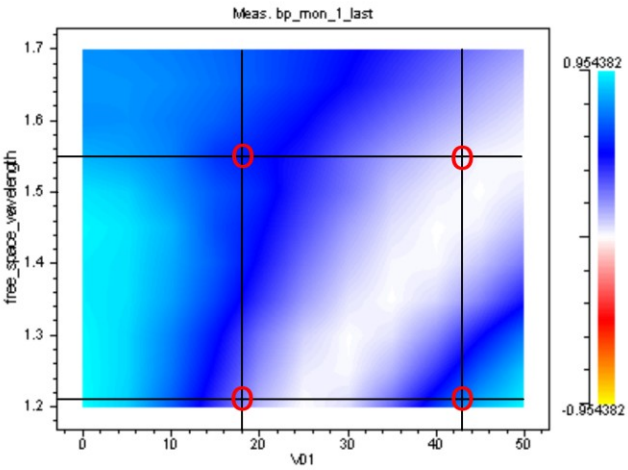

Fig. 2. Schematic design of an active reconfigurable node.

An analysis to obtain effect of voltage applied to electrodes on optical power at different values of voltage levels and different wavelengths was performed where background index and index difference were varied. Out of many cases simulated and studied, the case with index difference of 0.01 with background index of 1.57 is provided favorable results that may be explained by an example as follows. Consider a case of two wavelengths, λ_1 = 1210 nm and λ_2 = 1550 nm. From Fig. 2, as shown by red marker circles, if V1 is set at 43V, it is evident that at this voltage, λ_1= 1210 nm will pass (due to no phase difference), whereas λ_2= 1550 nm will undergo complete destructive interference and will not appear at the output end. Similarly, when V2 is set at 18V, λ_1 =1210 nm will undergo partial destructive interference whereas an attenuated λ_2 = 1550 nm wavelength will pass with about 70% of the input power. A better result for the latter case may be achieved at V2 = 25V. As a result, wavelengths = 1210 nm and λ_2 = 1550 nm will appear at the output as shown in Fig. 1. The same can be extended to other pair of wavelengths as well, given that they are separated considerably. Hence, both power and wavelength splitting, together applied can be used to achieve a device design for a reconfigurable optical node.

IV. Conclusion

A simulation study of an active reconfigurable optical node is presented here. An all-polymeric device structure is assumed and parameters accordingly are used in design simulation. The core material for all-polymeric device is assumed to be TCVDPA-doped-SU-8 electro-optic polymer with non-doped SU-8 as under and over-clad. An optical reconfigurable node is designed and simulated within a voltage limit of ± 50 V assuming PEDOT:PSS electrodes. The voltage applied to electrodes at device junctions configures the splitting ratio while applied at device branches configure the wavelength routing.

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