Silicon Photonic Integrated Mode Converter and Multiplexer for Few-Mode Fiber at 1550 nm

David García-Rodríguez, Juan L. Corral, Amadeu Griol and Roberto Llorente

Valencia Nanophotonics Technology Center, Universitat Politècnica de València (Spain);
dgarciarodriguez@ntc.upv.es

Abstract

Recently, significant research efforts have been focused on increasing optical fiber transmission capacity due to the rising demand of information transmission. The standard single mode fiber (SSMF) worldwide deployed operates exclusively in the infra-red band (1.3 µm-1.6 µm). Although the exploitable capacity in the infra-red band is substantial, it is showing signs of exhaustion even when using modern modulation schemes [1].

Mode-division multiplexing (MDM) is a good solution to overcome the limit on the fiber optics capacity. A mode (de)multiplexer to combine and split the modes at a certain wavelength is needed [1-2]. Different techniques have been proposed to convert and (de)multiplex the modes; for example, free space optics, liquid crystal on silicon (LCOS), directional couplers (DC), asymmetrical directional couplers (ADC) and long-period fiber Bragg gratings (LPFBG).

ADCs are a compact solution that allow to excite the higher order mode from the fundamental one. Different devices have been reported operating at wavelengths around 1550 nm [3,4] employing fibre-waveguide coupling. Mode conversion is induced by matching the effective index of the TE_1 mode in the waveguide 2 and the effective index of the TE_0 mode in the waveguide 1[5], as depicted in Fig. 1.

Depending on the selected fabrication technology, different options for the waveguide-fiber coupling have been considered. In Silicon-On-Insulator (SOI) technology, vertical coupling through a grating coupler or lateral coupling can be used. In this case, the grating coupler offers low losses [6] and the light coupling is less difficult compared with the horizontal case due to the huge difference between the dimensions of the fiber and the waveguide. Planar Lightwave Circuit (PLC) offers a lateral coupling with lower losses but at the expenses of a higher size and less compatibility with active photonic and electronic devices.

Grating couplers based on SOI are an interesting option to efficiently couple the TE_0 and TE_1 waveguide modes to the different modes of a Few Mode Fiber (FMF) [7]. Different techniques have been proposed to excite the LP_{11} mode in the FMF, like exciting one or several grating couplers with different copies of the TE_0 signal with the appropriate phases [8].

We propose and demonstrate a mode converter and multiplexer based on an asymmetrical directional coupler (ADC) fabricated in SOI technology, to couple simultaneously the TE_0 and TE_1 modes to the LP_{01} and LP_{11} modes directly in a Two Mode Fiber (TMF) through one single grating coupler.

References

[1] J.J. Benson Jr et al., "Striding Optical Transport Technologies to mitigate a Cyclical Capacity Crunch," Proc. OFC, **OTh4B.7**, Anaheim (2013).
[2] T. Uematsu et al.,"Low-loss and broadband PLC-type mode (de)multiplexer for mode-division multiplexing transmission", Proc. OFC, **OTh1B.5**, Anaheim (2013).
[3] J. Wang et al., "On-chip silicon 8-channel hybrid (de)multiplexer enabling simultaneous mode and polarization-division-multiplexing", Laser Photonics **Rev. 8, No. 2**, L18–L22 (2014).
[4] D. Dai et al., "Silicon mode (de)multiplexer enabling high capacity photonic networks-on-chip with a single-wavelength-carrier light", Optics Letters, **Vol. 38**, **no. 9**, pp. 1422-1424 (2013).
[5] N. Hanzawa et al., "Mode multi/demultiplexing with parallel waveguide for mode division multiplexed transmission", Optics Express, **Vol. 22, no. 24**, pp. 29321-29330 (2014).
[6] D. Dai et al., "Multi-channel Silicon Mode (de)multiplexer based on Asymmetrical Directional Couplers for on-chip Optical Interconnects", IEEE Photonics Society, **vol. 28, no. 2**, (2014).
[7] A. Li et al., "Fabrication of Low Loss Fused Fiber Spatial-Mode Coupler for Few-Mode Transmission", Photon. Technol. Lett., **Vol. 25, no. 20**, pp. 1985-1988 (2013).
[8] B. Wohlfei et al.,"Compact Fiber Grating Coupler on SOI for Coupling of Higher Order Fiber Modes", Proc. OFC, **OTh1B.2** (2013).

Acknowledgments

This work has been partially supported by Spanish Ministerio de Economía y Competitividad under Project RTC-2014-2232-3 HIDRASENSE and Spain National Plan project XCORE TEC2015-70858-C2-1-R.

Figures

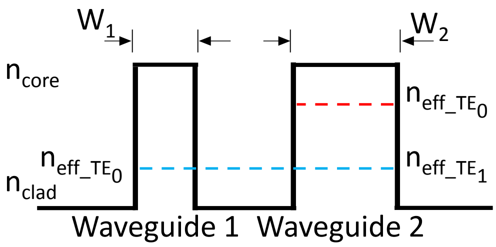

Fig. 1: Refractive index profile for mode coupling between TE_0 and TE_1 modes.

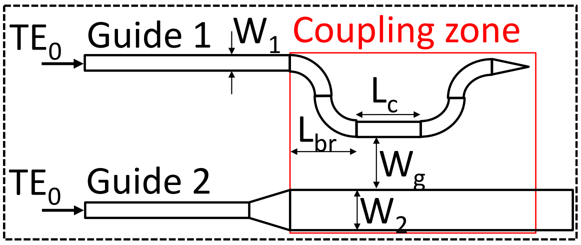

Fig. 2: Schematic structure of a mode multiplexer based on Asymmetrical Directional Coupler (ADC).

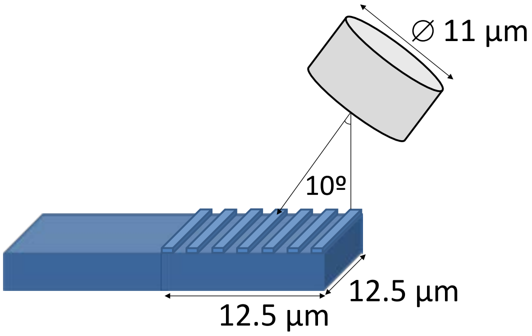

Fig. 3: Output grating designed to couple the LP_{01} and LP_{11} modes in the few-mode fiber (FMF)

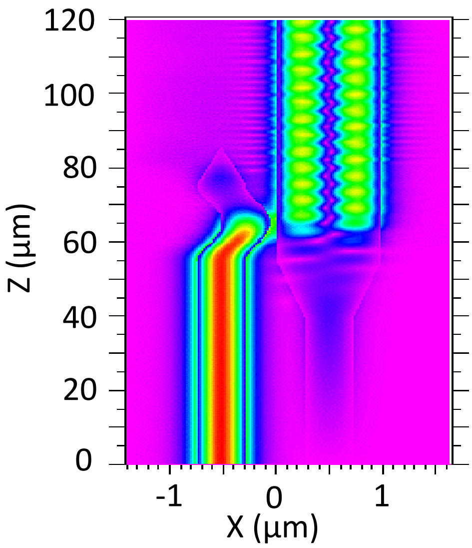

Fig. 4: BPM simulation of a mode multiplexer based on Asymmetrical Directional Coupler (ADC).

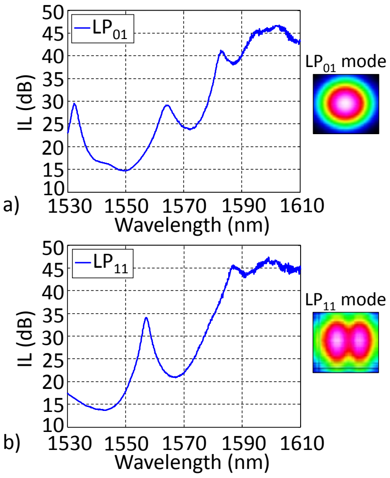

Fig. 5: Insertion losses for LP_{01} and LP_{11} modes. The insets show the field coupled to the few mode fiber (FMF)