COMPACT OPTICAL MEMS 1×N BEAM-SPLITTER BASED ON MULTI-MODE INTERFERENCE FOR OPTOFLUIDIC APPLICATIONS

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Integrated optical beam splitters are key element in different optical devices such as NxN coupler, wavelength multiplexer/demultiplexer and photonic integrated circuits [1]. Beam splitters based on multi-mode interference (MMI) waveguide have the advantages of simple fabrication and insensitivity to fabrication tolerance [2]. MMI beam splitters also have the advantage of being compatible with in-plane Micro-Electro-Mechanical Systems (MEMS) technology and can be easily integrated in a self-aligned manner with the other optical MEMS components on-chip opening the door for new promising applications [3]. In this work, we present the design and characterization of a 1xN beam splitter based on an MMI waveguide fabricated on MEMS technology. The proposed structure has the advantage of allowing the splitter to be used at wavelengths below the 1.1 µm silicon cut off wavelength that is needed for many optofluidic applications [3]. A compact splitter design achieved by guiding the light in air in a parallel plate waveguide structure with the lowest achievable guiding refractive index, with paired excitation in the input and parabolic tapering in the waveguide width along its length.

The proposed structure has guiding in only one direction parallel to the wafer surface and there is no guiding in the out of plane direction. Thus, a compact splitter design is required for low insertion loss splitter. This is achieved by using paired excitation with input excitation shifted by W/6 from the waveguide center, which reduces the splitter length by a factor of 3 compared to the general excitation [5]. Further fifty percent length reduction is achieved by tapering the waveguide width along its length with a parabolic shape with middle waveguide width reaches 60% of its value at the waveguide ends as shown in Fig. 1 [6]. The in-plane field is simulated using wide-angle finite difference beam propagation method (FD-BPM). The usage of a wide-angle technique [7] is required due to the large refractive index difference between Si and air. The input field is approximated as a Gaussian beam with the mode field diameter (MFD) of the single mode fiber (SMF) mode. The structure is simulated at wavelengths of 2200 nm, 1300 nm, and 980 nm, for 1x2, 1x3, and 1x4 splitters, respectively. Simulation results are shown in Fig. 2.

The structure is fabricated in a silicon-on-insulator (SOI) wafer using deep reactive ion etching (DRIE) technology. The waveguide patterning is fabricated precisely due to the very high accuracy of photolithography. A scanning electron microscope (SEM) image of the fabricated structure is shown in Fig. 3. The characterization is carried out using the setup shown in Fig. 4. The output profile is captured using a scanning slit beam profiler with a Ge detector and 25 µm slit width. The splitter output profile is measured at two different wavelengths of 1310 nm and 980 nm lasers. The measured profile is shown in Fig. 5. The splitter nearly acts as a 1x3 splitter at 1310 nm and as 1x4 splitter at 980 nm. The wide output profile and different peaks merging occur due to light diffraction, since the light propagates in the air for a few millimeters before reaching the beam profiler scanning head detector.

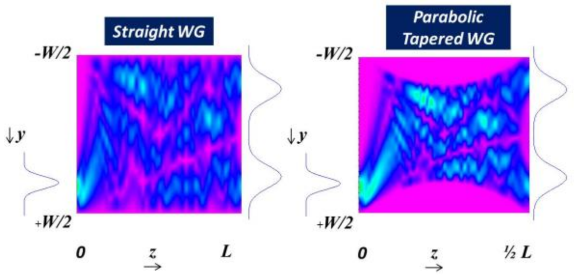

Fig. 1. Schematic illustrating the difference between straight and parabolic tapered waveguide.

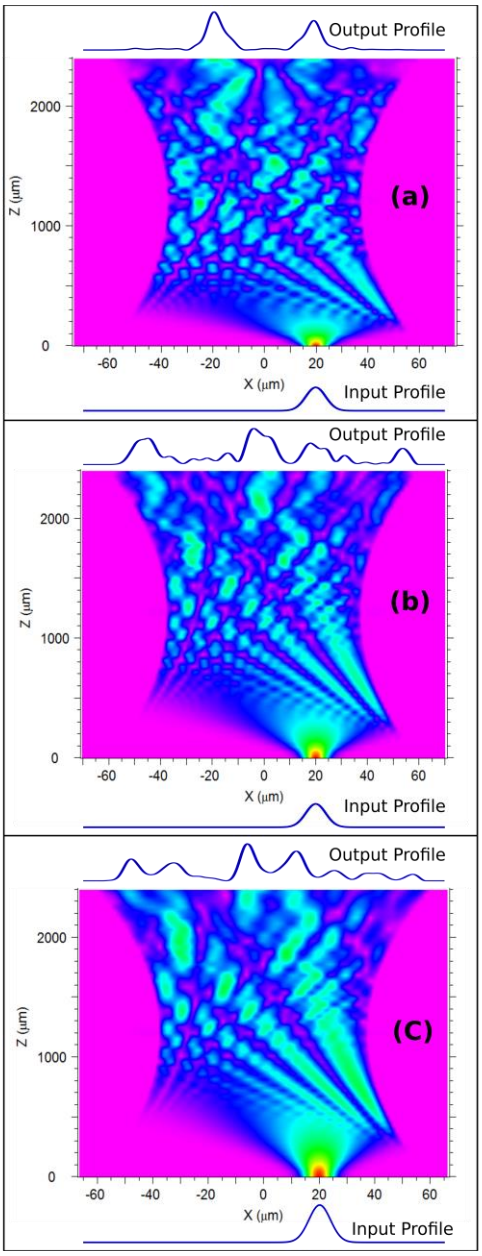

Fig. 2. Simulation contour plots for the field inside the MMI waveguide and the corresponding input and output field intensity profiles for (a) 2200 nm wavelength at which it acts as a 1x2 splitter, (b) 1300 nm wavelength at which it acts as a 1x3 splitter and (c) 980 nm wavelength at which it acts as a 1x4 splitter.

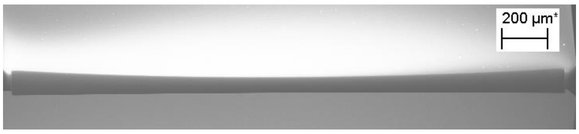

Fig. 3. Scanning electron microscope (SEM) image of the fabricated splitter on Si.

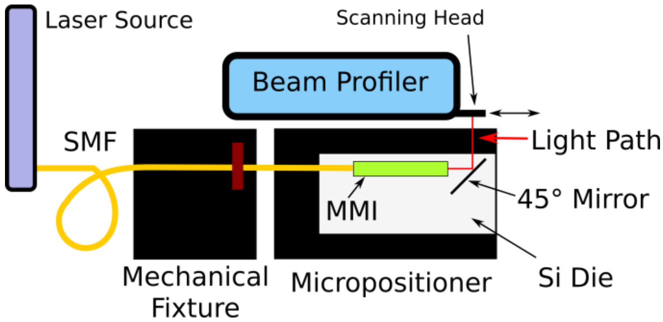

Fig. 4. Schematic diagram of the setup used in structure characterization.

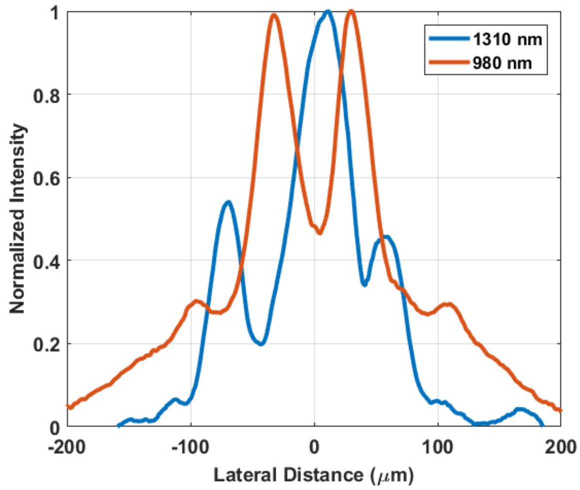

Fig. 5. Measured output intensity profile of the MMI splitter at input wavelengths of 1310 nm and 980 nm.

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