Abstract

Controllable splitting of optical power with a large splitting ratio range is often required in an integrated optical chip, e.g. for the readout of phase shift in a slow-light sensor. In this work, we report the design of an integrated optical programmable power splitter consisting of a Y-junction with programmable phase shifter cascaded to a directional coupler. We used a vectorial mode solver, and a combination of a transfer matrix method and a 3-D vectorial coupled-mode theory (CMT) to compute the power transfer ratio of a realistic device structure made of Si$_3$N$_4$, TEOS, and SiO$_2$ with cross-section as shown in the inset of the figure, and used the results to design a programmable power splitter with more than 20 dB power ratio range. In the simulations, waveguide attenuation values derived from measured attenuation of prefabricated test wafer, has been taken into account. Vectorial modal fields of mode of individual waveguide computed by a mode solver were used as the basis for the CMT computation. In the simulation, a wavelength around 632.8 nm was used. For simplification, the sine-bend parts of the coupler were replaced by circular bend in the simulation. Our simulations reveal that maximum power splitting ratio can be achieved when the directional coupler is operated as a 3-dB coupler with the phase shifter set to produce a 90° phase shift. The required coupler length for such desired operating condition is highly dependent on the gap size. On the other hand, the inclusion of the waveguide loss and the non-parallel section of the directional coupler into the model only affect the results weakly.

Keywords: power splitter, directional coupler, transfer matrix method, coupled-mode theory.