Ultra compact and low loss multimode interference splitter for arbitrary power splitting

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Abstract—Arbitrary power splitting ratio is obtained by an 1-to-2 asymmetric multimode interference splitter. The dimension of the multimode section is less than 1.5 μm × 3 μm while the excess loss is lower than 0.15 dB.

Keywords — Silicon photonics, multimode interference, arbitrary-ratio power splitter.

I. INTRODUCTION

Multimode interference (MMI) splitter is attractive for integrated silicon photonics due to the merits of large fabrication tolerance, wide bandwidth, and compact size [1]. Free choice of power splitting ratio is one of the chief properties of power splitter demanded by integrated functional photonics systems, such as Mach-Zehnder interferometer (MZI) when the losses of MZI arms are different[2,3]. Several methods have been reported aiming at arbitrary power splitting ratio such as multiple-arm MZI consisting of an active phase-shifting region placed between two MMI couplers [5], cascaded MMI with unequal width waveguide interconnection [6], and MMI with computer-generated planar holograms [7,8]. However, all these methods suffer from relatively complex structure and large footprint.

In this paper, we present an ultra compact and low loss 1-to-2 MMI splitter with arbitrary power splitting ratio by means of breaking the symmetry of the multimode region. The dimension of the multimode section is less than 1.5 μm × 3 μm and the excess loss is lower than 0.15 dB while the power splitting ratio can be adjusted from 0%:100% to 50%:50%.

II. ARBITRARY-RATIO POWER SPLITTER DESIGN

Figure 1(a) shows the schematic of conventional symmetric 1×2 MMI splitter. Due to its structural symmetry, it only allows uniform split of the incident light into two output ports. The simulated energy flux (Pz) and field distribution (Hy), shown in Fig. 1(c) and (d), indicate that there is little energy and field distribution in the left corners (marked with dashed red ellipse) of the multimode region. However, removing one of the left corners will break the symmetry of interference. According to self-imaging principle, general interference will replace symmetric interference at the asymmetric multimode region accordingly [9]. That is to say, removing certain area from the left corner will change the power splitting feature while no significant excess loss is induced benefiting from exiguous energy and field distribution in the removed region.

![Fig.1.](image_url)

As shown in Fig. 2(a), the symmetry of the multimode region is broken by removing its up left corner (marked with red dashed line). From Fig. 2(b, c), it is apparent that such minor structural change causes dramatic redistribution of energy and field. Utilizing the first two-fold images, the power output from port 2 is significantly greater than from port 1. Based on this principle, arbitrary-ratio power splitter with low excess loss can be achieved.

To demonstrate its working principles, a rectangular of 400 nm in width (W) is removed from left corner. Different length of the rectangular (Lr) will yield different power splitting ratio (defined as the output power from one port divided by the total output power from two ports). Relation between power splitting ratio and the removed rectangular length (Lr) is shown in Fig. 3 (the red dots and line). It indicates that the splitting is adjustable from 0%:100% to 50%:50%. Since the removed region contains little energy and electromagnetic field, the excess loss of the proposed structure is insignificant, only ~0.15 dB as shown in the blue crosses and line of Fig. 3.

Energy flux densities corresponding to different removed rectangular length (Lr) are shown in Fig. 3. It shows that the energy flux increase at port 2 with longer Lr. At the same time, the first two-fold images shifts slightly towards farther position,
that is, the length of the multimode region is increasing. However, the length of the multimode region is less than 3 \( \mu \)m for all cases, sufficiently small for large-scale integration.

Further analysis on wavelength dependence of power splitting ratio is shown in Fig. 5. The splitting ratio variation of the proposed MMI is less than 7% while input wavelength covers a broadband from 1450 nm to 1650 nm. This indicates that the proposed MMI with arbitrary power splitting ratio is wavelength insensitive, which is essential for broadband applications.

### III. CONCLUSION

This work proposes an ultra compact and low loss 1-to-2 MMI splitter for arbitrary power splitting. The power splitting ratio can be adjusted from 0%:100% to 50%:50% by breaking the symmetry of the multimode region with minor structural removal such as rectangular. The dimension of the multimode section is less than 1.5 \( \mu \)m \times 3 \( \mu \)m while excess loss does not exceed 0.15 dB. 3D full vector simulations indicate insignificant wavelength dependence over a broad wavelength range. In summary, the results presented in this work suggest that the proposed MMI splitter is suitable for dense integration due to the merits of extremely compact footprint, low excess loss, simple structure and arbitrary power splitting ratio, promising for wide applications including power taps, Mach-Zehnder interferometer, etc.

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### REFERENCES