1×3 plasmonic power splitter for various splitting ratio

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Abstract: A 1×3 plasmonic power splitter for various splitting ratio is proposed by using a rectangular ring resonator based on metal-insulator-metal waveguide. The input/output waveguides are located at which destructive/constructive interferences of this ring interferometer are occurred, respectively. Then flexible splitting ratio is realized by manipulating the output waveguide widths and the minimized reflectance in the input waveguide is numerically accomplished by adjusting the resonator's dimension.

Introduction: Plasmonic power splitters that divide an input power into two or more output ports have been considered as a key component for both signal routing and signal processing in ultrahigh-density photonic integrated circuits (PICs)[1-3]. In particular, power splitters with flexible power splitting ratio are required in many applications, such as in a communication system[4]. In addition, 1×3 splitters are required as one elementary building block to build a 1×N optical splitter[5]. Various 1×3 plasmonic splitters are proposed to manipulate the splitting ratio by adjusting the coupling lengths in the couplers[1], varying the gap widths between waveguides and the cavity[2] and shifting the waveguide positions along the multimode interference waveguide[3]. However, these splitters are high sensitive to the wavelength variation. In this work, we present a 1×3 plasmonic power splitter constructed by a rectangular ring resonator with directly-connected input and output waveguides based on the metal-insulator-metal (MIM) waveguides. The input/output waveguides are located where destructive/constructive interferences of this ring interferometer are occurred, respectively. The splitting ratio is controlled by adjusting the output waveguide widths, and the reflectance at the input waveguide is eliminated by adjusting the waveguide width of resonator. Due to the direct connection and the conditions for interferences, the qualify factor of this resonator is low, and thus this device provides the characteristics of broad bandwidth. An example of a 1x3 plasmonic power splitter is numerically demonstrated.

1×3 plasmonic splitter: The configuration of a 1×3 plasmonic splitter based on MIM waveguides is shown in Fig. 1. The input and three output waveguides are directly connected to a rectangular ring resonator. The widths of input waveguide and three output waveguides are w_{in}, $w_{out,1}$, $w_{out,2}$ and $w_{out,3}$, respectively. The width and the height of the resonator are W and H, respectively. The waveguide width of the resonator is w_r.. Due to the impedance mismatched of the T-splitter at each junction of the input/output waveguide, bidirectional propagation waves travel inside the resonator, resulting in an interference pattern of the field distribution along the resonator. Thus, to obtain three anti-nodes of the interference pattern where all the output waveguides are located, the total propagation phase in the resonator is equal to 3π. To realize the minimal reflection at the input waveguide, the input waveguide is located at one node of the interference pattern. The interference conditions related to the waveguide parameters become $Re\{\beta_r\}H=0.5\pi$ and $Re\{\beta_r\}W=\pi$, where $Re\{\beta_r\}$is the real part of the propagation constant of the resonator. The output power in each output waveguide is proportional to its width, and then the splitting ratio of this device can be realized by adjusting the width ratio, $w_{out,1}$, $w_{out,2}$ and $w_{out,3}$. In addition, in order to minimize the reflectance, the waveguide width of the resonator w_r is adjusted to have a completely destructive interference in the input waveguide. Thus, w_r, W and H are relevant, and we iteratively obtain all design parameters to reach the desired splitting ratio and a negligible reflectance.

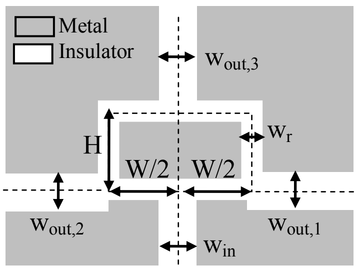

Fig. 1: Structure of the 1x3 splitter

Simulated results: We numerically exhibit an example of the 1×3 power splitter with various splitting ratio. The dielectric and metallic materials of MIM waveguides are air and silver, respectively. The permittivity of silver is described by the Drude-Lorentz model[6]. The concerned wavelength is 1550nm. Suppose that the splitting ratio is 1:2:3. First, let w_0=$w_{out,2}$=50nm and set $w_{out,1}$=25nm, $w_{out,3}$=75nm and w_r=50nm as our initial guessing. Then, $w_{out,1}$ and $w_{out,3}$ and w_r are modified to obtain the specifications. The optimized parameters are as follows: $w_{out,1}$=15nm, $w_{out,3}$=80nm and w_r=40nm. Then, the corresponding H=259.6nm and W=519.2nm. The field evolution of this 1x3 splitter at the wavelength of 1550nm simulated by using the two-dimensional (2D) finite difference time domain (FDTD) simulator (Fullwave, RSOFT Design Inc.) is depicted in Fig. 2(a). The transmittances in the output waveguides are -8.2, -4.8 and -3.3 dB, respectively, showing the splitting ratio is approximately 1:2:3. The reflectance in the input waveguide is -32.0dB. The wavelength dependence of this device is shown in Fig. 2(b). The splitting ratio is roughly 1:2:3 over the wavelength range between 1400 and 1700nm, showing that the splitting ratio slightly vary with the wavelength. The wavelength dependence of reflectance is shown in Fig. 2(c). The reflectance in the input waveguide is less than -20dB as the wavelength ranges between 1400 and 1700nm. These simulated results show that this device has a flat and wide band due to the low qualify factor of this resonator.

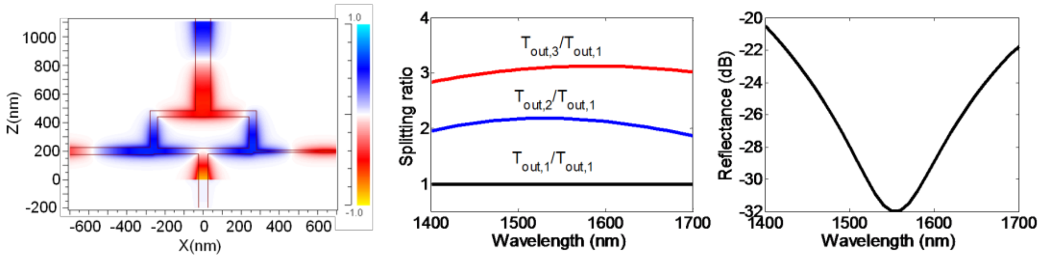

Fig. 2: (a) Field evolution (b) Splitting ratio (c) Reflectance spectrum

Conclusion: A 1×3 plasmonic power splitter constructed by a rectangular ring resonator is proposed to reach various splitting ratio for the applications in ultrahigh-density PICs. The input and output waveguides are located at the one node and three anti-nodes of the interference pattern of the field distribution along the resonator. Then, the splitting ratio is manipulated by adjusting the waveguide width ratio among the output waveguides and the minimized reflectance is obtained by adjusting the resonator dimension. Due to the direct connection and the conditions for interferences, the qualify factor of this resonator is low, and thus this device provide the characteristics of broad bandwidth. An example of the 1×3 plasmonic splitter with its dimension of 259.6nm×519.2nm and a splitting ratio of approximately 1:2:3 and reflectance below -20dB over the range of 1400 to 1700nm is numerically demonstrated.

References

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