طراحی گیت‌های منطقی نوری مبتنی بر تکنولوژی تزریق سیال

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چکیده – در این مقاله گیت‌های منطقی نوری اصلی از جمله OR و NOT که مبتنی بر تکنولوژی تزریق سیال و ساختار موج برهای فلزی شیاردار هستند معرفی شده‌اند. گیت‌های منطقی پیشنهادی با کمک روش تحلیل FDTD شبیه‌سازی شده است. ساختار پیشنهادی پایه برای طراحی گیت های منطقی اشاره شده مبتنی بر اتصالات به شکل Y با کنترل کننده های متفاوت برای پورت‌های ورودی و خروجی هستند. گیت‌های منطقی پیشنهادی می‌توانند به عنوان تجهیزات کلیدی در پردازش سیگنال‌های نوری مورد استفاده قرار بگیرند.

کلید واژه- پردازش سیگنال نوری، تداخل، سیال نوری، گیت های منطقی، موجبر فلزی شیاردار.

Designing of optical logic gates based on optofluidic technology

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Abstract- In this paper, compact all-optical AND, OR and NOT gates based on metal slot waveguide and optofluidic technology have been proposed. The logic gates have been simulated by finite difference time domain (FDTD) method. The principle structure for designing of mentioned logic gate is based on a single Y-shaped junctions with different controllers for input and output ports. The proposed optical logic gates can be used as key components in optical signal processing.

Keywords: Interferometric, Logic gates, Metal Slot Waveguide, Optical Signal Processing, Optofluidic.

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1 Introduction

Recently, optical logic gates have attracted wide attention because of their applications in optical computing systems. As is known, because of limitation in semiconductor-based electronic devices, photonic circuits have been proposed to break this limitation. Logic operation can be designed by constructive or destructive interference of the input signals [1-3]. Because of existence of surface plasmon between metal and dielectric and diffraction of light in photonic devices, Surface Plasmon Polaritons (SPPs) can be applied. By using SPPs, electromagnetic wave can couple to metal-dielectric interfaces [4]. SPPs overcome the conventional diffraction limit so can be used in highly integrated optical circuits. Recently, D. Pan et. al, realized optical logic gates based on propagating plasmon on metal slot waveguides because of their good field confinement [5]. In this paper, compact all-optical AND, OR and NOT gates based on metal slot waveguide and optofluidic technology have been proposed. The principle structure for designing of mentioned logic gate is based on a single Y-shaped junctions with different controllers for input and output ports. A single Y-shaped waveguide structure with two controllers for input ports can work as AND logic gates. By using mentioned structure and three controllers for input and output ports, NOT gate can be realized. The proposed optical logic gates can be used as key components in optical signal processing.

2 Logic gates with two input ports and two different controllers

As shown in Figure 1, this structure is designed in silver film which is coated on SiO_2 substrate. Two input ports are defined as a channel for signals which are denoted by I_1, I_2. In this device, two controllers which contain different materials are taken for input signals. Optical signals are transmitted from the input ports then interfere with each other and result output in the port O. Logic operations in our structure can be implemented using optofluidic technology as a controller. The amplitude of transmitted powers for the two signals are E (I_1) and E (I_2). In this structure, controllers have been used for input ports instead of determining phases between input signals to reach logic operations in output port. By defining different intensities and same phases for input signals and using controllers, three ports device can work as OR gate. In this paper, we assume the wavelength of 658nm with corresponding permittivity of silver $-18.36 + 0.48i$, [6].

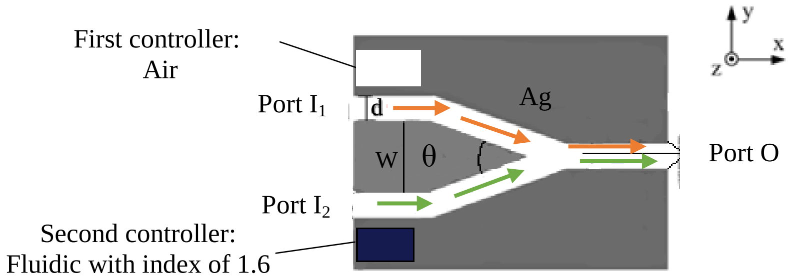


Figure 1: Sketch of two input port logic gate based on slots in Ag film with two controllers.

Table 1: Working principle of two input ports gates with two controllers (OR gate).

Input $\{E(I_1),E(I_2)\}$	Output amplitude	Output Intensity
{0,0}	0	0
{E,0}	E	$\lvert E\rvert^2$
{0,E}	E	$\lvert E\rvert^2$
{E,E}	2E	$4\lvert E\rvert^2$
Input controllers= First contains Air, second contains fluidic with index of 1.6		

The working principle of two input ports gates with two controllers is illustrated in Table 1. The output state is “1” for input {E, 0}, {0, E} and {E, E} when two controllers have been used. To verify the functions of OR logic gate, simulations based on finite difference time domain (FDTD) method are performed. The thickness *t* and width of waveguide *d* is set to 100nm and 60nm, respectively, in order to obtain good confinement and acceptable loss. As can be seen the electric field is mainly confined in this slot. To decrease the energy loss at the junction, small angle between the two input waveguide have been selected. After consideration, θ is chosen to be 30° [6].

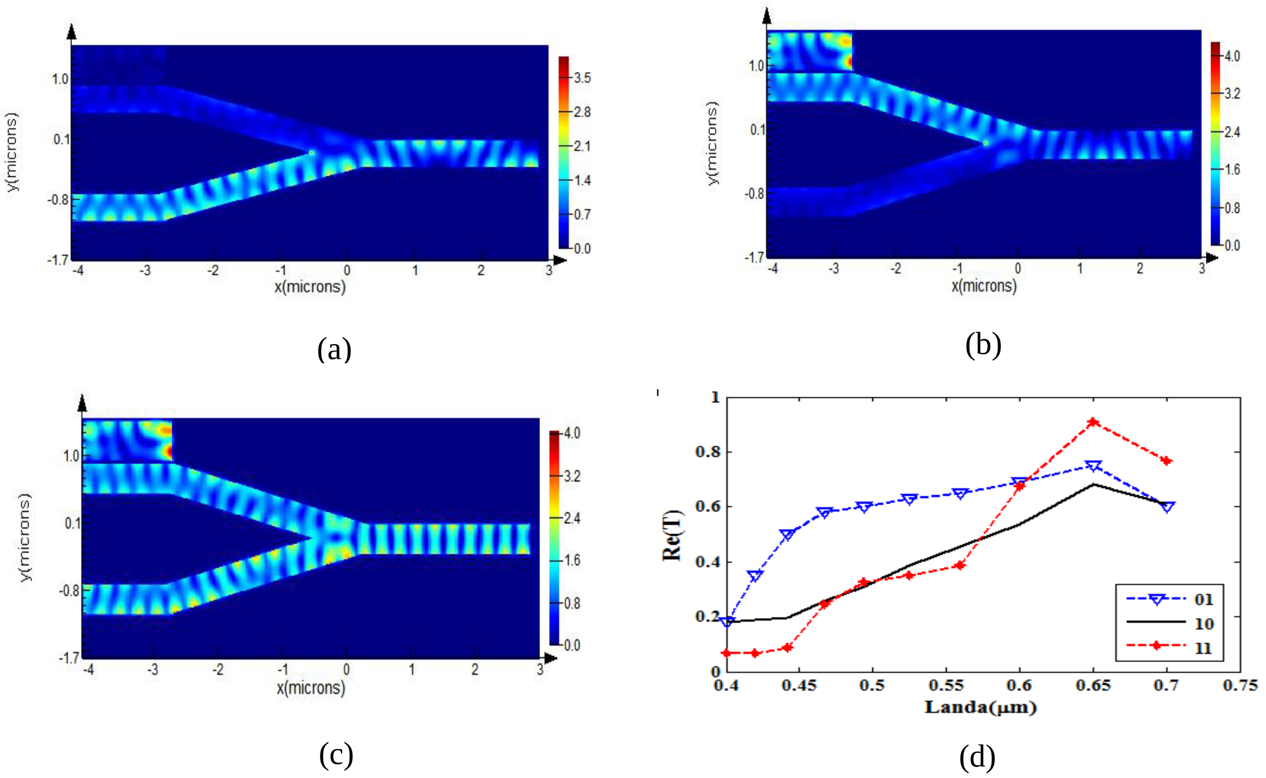


Figure 2: Distribution of field intensity and transmission for OR logic gate. (a), (b), (c) and (d), correspond to (a) only one input at port 2; (b) only one input at port 1; (c) two input signals and (d) transmission for different input patterns.

Figures 2(a)-2(d) correspond to (a) only one input signal at port 2, (b) only one input signal at port 1, (c) two input signals and (d) transmission, show the distribution of field intensity and transmission of different input patterns for OR logic gate. It is clear that the intensity contrast for the output value “1” and “0” is high. As shown in figure 2(d), in wavelength of 0.65µm, the maximum of transmission can be obtained in different input patterns which indicates output state is “1” for input {E, 0}, {0, E} and {E, E}. So the functions of OR logic gate can be verified.

3. Logic gate with two input ports and three different controllers

The sketched structure of the logic gate with three controllers is shown in Figure 4. As is shown, in second structure, one more controller has been used for output port. Thus NOT logic gate can be realized in such structure. The ports I_1 and I_2 are used for input signals, while Port O is the output of the whole structure. All the parameters are denoted similar as in last section.

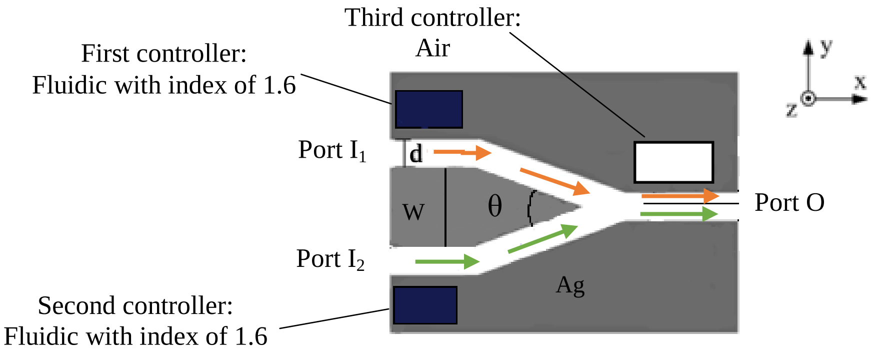
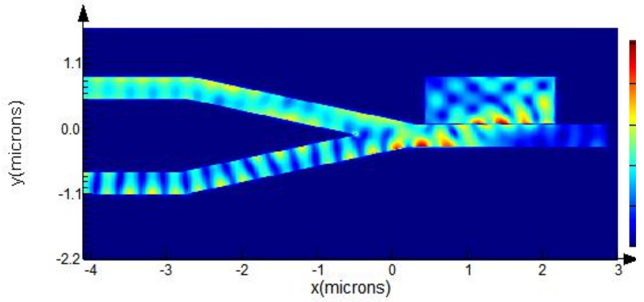


Figure 3: Sketch of two input ports logic gate with three controllers

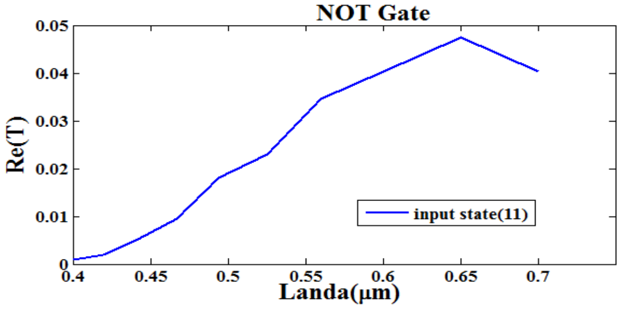
Table 2: Working principle of two input ports gate with three controllers (NOT gate).

Input {E(I$_1$),E(I$_2$)}	Output amplitude	Output Intensity
{E,0}	0	0
{0,E}	0	0
{E,E}	0	0
Input controllers= Contain fluidic with index of 1.6 Output controller = Contains Air		

The working principle of NOT gate is shown in Table 2. It shows when controllers have been used for input and output ports, the output state is opposite to the input state, which indicates function of NOT gate. FDTD method was performed to investigate the outputs of the device quantitatively. Figures 4(a)-(b) show the distribution of field intensity and normalized transmission for operating NOT gate, correspond to two input signals. As shown in figure 4(b), in wavelength of 0.65µm, the minimum of transmission can be obtained in state (11) of input signals which means the output state is opposite to the input state (the input state is 1 but the output state is 0), which indicates function of NOT gate.



(a)



(b)

Figure 4: Distribution of field intensity and transmission for NOT logic gate. (a), (b), correspond to (a) distribution of two input signals (b) transmission of two input signals

4. Conclusion

In this paper, compact optical AND, OR and NOT gates based on metal slot waveguide and optofluidic technology have been proposed. The principle structure for designing of mentioned logic gate is based on a single Y-shaped junctions with different controllers for input and output ports. A single Y-shaped waveguide structure with two controllers for input ports can work as AND logic gates. By using mentioned structure and three controllers for input and output ports, NOT gate can be realized. The working principle is discussed in detail and the working efficiency is verified by electromagnetic simulations and FDTD method. The logic gates based on metal slot waveguide and optofluidic technology show small sizes and intensity contrasts for the output states “1” and “0”. The proposed optical logic gates can be used as key components in optical signal processing.

5. References

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