# Analysis of normalized input power for optical pulse wavelength selective switch array

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In this paper, we research the influence of two-photon absorption effect for optical pulse wavelength selective switch array. Because two-photon absorption effect can make the shape of optical pulse change, the relative extinction ratio will be seriously affected. As long as normalized input power is well controlled, the influence of two-photon absorption can be minimized and the relative extinction ratio will be not clearly changed. Then, the function of pulse wavelength selection is well realized. It is beneficial to actually guide to fabricate an optical pulse wavelength selective switch array.

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## 1. Introduction

Because of its Kerr nonlinearity and tight mode confinement, Silicon-on-insulator (SOI) [1] has been widely used for some optical devices, such as optical switches. There is much research about micro-ring continuous-wave optical wavelength selective switches. However, there is little research about micro-ring optical pulse wavelength selective switches [2,3]. So, we research the micro-ring optical pulse wavelength selective switch array (OPWSSA) based on SOI. The coupling between micro-ring and straight waveguides uses the linear negative tapered SOI Bragg Grating (LNTSBG). Because of two-photon absorption (TPA) effect in the SOI can make optical pulse shape change, the relative extinction ratio (RER) will be seriously affected. As long as normalized input power (NIP) is controlled between 22w and 24w, RER will be below 0.7%. The influence of TPA can be ignored. The function of optical pulse wavelength selection will be still realized. It guides theoretically to fabricate OPWSSA.

## 2. Design of optical pulse wavelength selective switch array

The micro-ring coupled with straight waveguides assisted by LNTSBG, as shown in the Fig. 1. Applying Kerr nonlinearity and Bragg wavelength selectivity, different wavelength optical pulses will export to diverse output ports.

Fig. 1a shows the whole construction of OPWSSA. $Lc_i\ i=1,2...n$ is coupling length, and $Lc_2 = 23.328\mu m$ for $\lambda_2 = 1.55\mu m$ .The wavelength difference is $\Delta\lambda = \lambda_i - \lambda_{i-1} = 8nm$ . The distance between micro-ring and waveguide is $\nu_i\ i=1,2,...n$ . And, $\nu_2 = 124nm$ . The distance difference is $\Delta\nu = \nu_i - \nu_{i-1} = 10nm$ . Also, $R_i = 10\mu m\ i=1,2,..n$ .

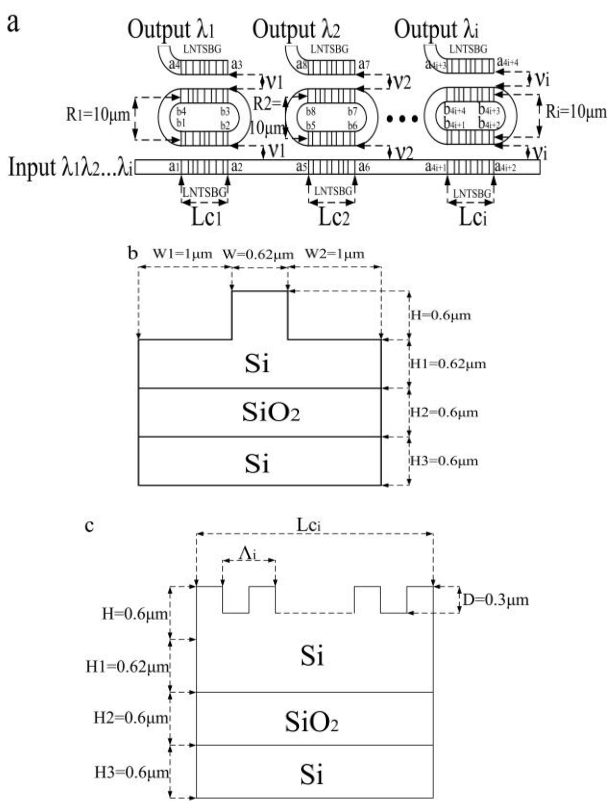

*Fig. 1. Optical pulse wavelength selective switch array. (a) Construction of switch array. (b) Cross-section of micro-ring resonator and waveguides. (c) Longitudinal section of LNTSBG.*

Fig. 1.b illustrates the cross-section of micro-ring and waveguides. These cross-sections are ridge shaped. $W = 0.62\mu m$ is ridge width, $H = 0.6\mu m$ is ridge height, $W_1 = W_2 = 1\mu m$ is shoulder width, $H_1 = 0.62\mu m$ is thickness of Si layer. $H_2 = 0.6\mu m$ is thickness of SiO2 cladding layer. $H_3 = 0.6\mu m$ is thickness of Si cladding layer.

Fig.1.c shows the longitudinal section of LNTSBG. $D = 0.3\mu m$ is an etching depth. $\Lambda_i = m\lambda_{Bi} / 2\bar{n}_{effi}$ $i = 1, 2...n.$ is Bragg period, $m = 10$ is order number. $\lambda_{Bi}$ is a designed Bragg wavelength. $\bar{n}_{effi}$ is an average effective refractive index.

## 3. Theoretical mode

For two-core variable coupling coefficient nonlinear directional coupler assisted by LNTSBG, the coupled nonlinear Schrödinger equations (CNLSES) [4,5] are as follows:

$$\frac{\partial u_1}{\partial \xi} = -\frac{1}{2} i \frac{\partial^2 u_1}{\partial \tau^2} - \frac{\Gamma}{2} u_1 + iQ_{12} u_3 + ip_{g1} u_2 + io_1 u_1 + i(|u_1|^2 + 2|u_3|^2) u_1 + i\frac{\xi}{2} |u_1|^2 u_1 \tag{1a}$$

$$\frac{\partial u_2}{\partial \xi} = -\frac{1}{2} i \frac{\partial^2 u_2}{\partial \tau^2} - \frac{\Gamma}{2} u_2 + iQ_{21} u_1 + ip_{g2} u_4 + io_2 u_2 + i(|u_2|^2 + 2|u_1|^2) u_2 + i\frac{\xi}{2} |u_2|^2 u_2 \tag{1b}$$

$$-\frac{\partial u_3}{\partial \xi} = -\frac{1}{2} i \frac{\partial^2 u_3}{\partial \tau^2} - \frac{\Gamma}{2} u_3 + iQ_{12} u_4 + ip_{g1} u_1 + io_1 u_3 + i(|u_3|^2 + 2|u_4|^2) u_3 + i\frac{\xi}{2} |u_3|^2 u_3 \tag{1c}$$

$$-\frac{\partial u_4}{\partial \xi} = -\frac{1}{2} i \frac{\partial^2 u_4}{\partial \tau^2} - \frac{\Gamma}{2} u_4 + iQ_{21} u_2 + ip_{g2} u_3 + io_2 u_4 + i(|u_4|^2 + 2|u_2|^2) u_4 + i\frac{\xi}{2} |u_4|^2 u_4 \tag{1d}$$

Where $A_1$ is an amplitude of chirped Gaussian pulse. The initial amplitude of

$A_1$ is $A_1(0,t) = A_0 \exp[-((1-2i)/2)(t/T_0)^2]$ , $A_0 = \sqrt{P_{in}}$ and

$i = \sqrt{-1}$, initial pulse width $T_0 = 0.02 \times 10^{-12} s$ and initial

pulse $A_2(0,t), A_3(0,t), A_4(0,t) = 0$.

$u_i = (\gamma L_D)^{1/2} A_i$ $i = 1, 2, 3, 4$ are normalized amplitudes in two cores. $\gamma$ is nonlinear coefficient. $Q_{21} = \kappa_{g1} L_D X$ , $Q_{12} = \kappa_{g2} L_D X$ is normalized coupling coefficient.

$X = \exp(-|z/2|)$ is exponential coefficient [6].

Also, $\Lambda_2 = 2.335\mu m$.

$\kappa_{gi} = \pi\bar{n}_{effi} / \lambda_{Bi}$ $i = 1, 2...n$ is Bragg coupling coefficient.

$p_{gi} = \kappa_{gi} L_D [1 - 0.25(z - L_C/2)/L_C]$ $i = 1, 2...n$ is normalized linear negative tapered grating coupling coefficient. $o_i = \delta_i L_D$ $i = 1, 2...n$ is normalized detuning coefficient.

$\delta_i = 2\pi\bar{n}_{effi}(1/\lambda_{Bi} - 1/(\lambda_{Bi} + \Delta\lambda_{Bi}))$ $i = 1, 2...n$ , $\lambda_{Bi}$ is pump wavelength.

$\Gamma = \alpha L_D$ is normalized attenuation factor and $\alpha = 2.3 \times 10^{-3} dB/m$. $L_D = T_0^2 / |\beta_2|$ is dispersion length with $\beta_2 = \text{-}2.15 \times 10^{-24} s^2/m$ . $\beta_{11} = 8 \times 10^{-12} m/W$ is TPA coefficient. $\xi = \beta_{11} \times L_d$ are normalized TPA coefficient. Where $P_1$ is NIP. $P_{in} = 0.0745 \times P_1$ is a real input power.

## 4. Simulations and results

The power transmission efficiency $T_i$ can be defined as follows [7].

$$T_i = (P_i / P_0) \times 100\% \qquad i = 1, 2. \qquad (2)$$

$P_0$ is input pulse power, $P_2$ is output pulse power in one output port, $P_1$ is remaining power in the other waveguides.

Fig. 2 shows the change of power transmission efficiency for $\lambda = 1.55\mu m$, when P1 increases. It is easily found that normalized threshold power $P_T = 18.012w$. Similarly, we can obtain normalized threshold power $P_T = 18.037w$ for $\lambda = 1.558\mu m$, $P_T = 17.956w$ for $\lambda = 1.542\mu m$, and so on.

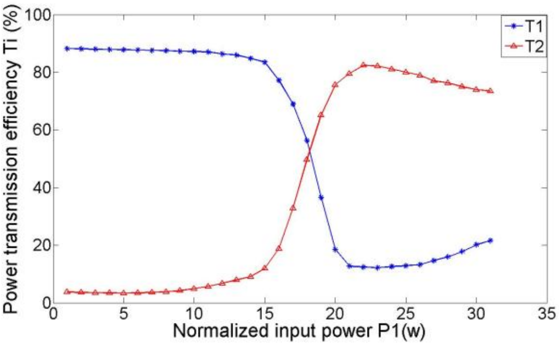


*Fig. 2. Power transmission efficiency for* $\lambda = 1.55\mu m$.

Also, the relative extinction ratio (RER, $\eta$) can be defined as follows,

$$\eta = (|E_1 - E_0|) / E_0 \times 100\% \qquad (3)$$

$E_0$ represents ideal extinction ratio (ER),which have no TPA effect. While $E_1$ shows ER with TPA effect.

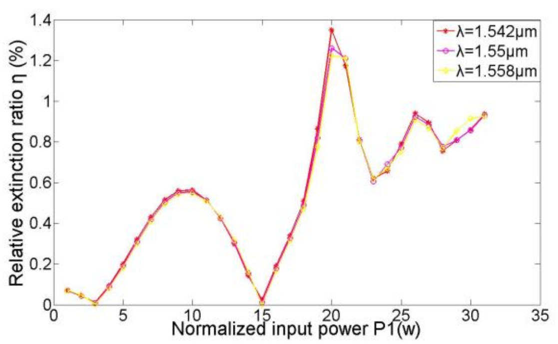


*Fig. 3. Relative extinction ratio* $\eta$.

Fig. 3 depicts $\eta$ variation for three different wavelengths, when $P_1$ increases. As long as $22w \le P_1 \le 24w$, $\eta$ gets minima and these values are below than 0.7%. That is, $P_1 \in [22w, 24w]$ is input power tolerance interval. The influence of TPA can be ignored in this interval, and the optical pulse wavelength selection can be well realized.

## 5. Conclusions

In this paper, we research the two-photon absorption effect for optical pulse wavelength selective switch array. Because two-photon absorption effect can make input optical pulse change, the relative extinction ratio will be seriously affected. But, if we control the normalized input power in the power tolerance interval, then, the relative extinction ratio is below 0.7%. The consequence of two-photon absorption effect can be neglected. The function of pulse wavelength selection can be still realized. It is beneficial to guide an actual optical pulse switch array fabrication.


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