Photonics and Nanostructures – Fundamentals and Applications 29 (2018) 15–21

Contents lists available at ScienceDirect

Photonics and Nanostructures – Fundamentals and Applications

journal homepage: www.elsevier.com/locate/photonics

Design and implementation of optical switches based on nonlinear plasmonic ring resonators: Circular, square and octagon

Majid Ghadrdan, Mohammad Ali Mansouri-Birjandi*

Faculty of Electrical and Computer Engineering, University of Sistan and Baluchestan, P. O. Box 9816745563, Zahedan, Iran

ARTICLE INFO

Article history:
Received 18 November 2017
Received in revised form 13 January 2018
Accepted 16 January 2018

Keywords:
Nonlinear Kerr Effect
All-optical switches (AOS)
Plasmonics
Ring resonator (RR)

ABSTRACT

In this paper, all-optical plasmonic switches (AOPS) based on various configurations of circular, square and octagon nonlinear plasmonic ring resonators (NPRR) were proposed and numerically investigated. Each of these configurations consisted of two metal-insulator-metal (MIM) waveguides coupled to each other by a ring resonator (RR). Nonlinear Kerr effect was used to show switching performance of the proposed NPRR. The result showed that the octagon switch structure had lower threshold power and higher transmission ratio than square and circular switch structures. The octagon switch structure had a low threshold power equal to 7.77 MW/cm^2 and the high transmission ratio of approximately 0.6. Therefore, the octagon switch structure was an appropriate candidate to be applied in optical integration circuits as an AOPS.

© 2018 Elsevier B.V. All rights reserved.

1. Introduction

Nowadays, signal processing techniques develop into the all-optical stage and attract the attention of many researchers and scientists. The optical elements such as filters [1,2], analog-to-digital converters [3], logic gates [4–6], splitters [7], multiplexers [8,9], and all-optical switches (AOS) [10–14] are proposed at this stage. Optical information processing and optical communication are based on the AOS, therefore, the AOS are a key technology of all-optical signal processing technology.

Various types of the AOS based on different working principles have been demonstrated. These proposed structures have different characteristics, functions, and application in different situations. Among these, the AOS based on surface plasmon polaritons (SPPs) have attracted much attention owing to ultra-fast response time and nanometer scale [15–19].

SPPs are electromagnetic waves propagating at the interface between a dielectric and a metal. The maximum of the electromagnetic field is located at the interface and exponentially decays into the dielectric and metallic regions. When the metallic structures dimensions are comparable with the optical wavelength, SPPs are excited [20,21].

The use of optical nonlinear effects such as Kerr-type nonlinearities is a fascinating approach for the AOPS, because these nonlinear switches can be operated with an ultra-fast response time, nanometer scale and low threshold power [18,22]. In addition, some structures are used for all-optical plasmonic switches (AOPS), including cavities [23–26], Mach-Zehnder interferometers [27–30], directional couplers [31–33], and ring resonators (RRs) [34–38]. Among these structures, RRs structures have appeared as an interesting candidate for guiding and switching.

In this research, we demonstrate three AOS based on various configurations of circular, square and octagon nonlinear plasmonic ring resonators (NPRR). Nonlinear Kerr effect is used to show the switching performance of the proposed NPRR. The transmission spectra and the required switching powers for different configurations are compared. The performance of our proposed switches is investigated by the finite-difference time-domain (FDTD). All the presented structures have the potentiality to be applied in optical integration circuits and nano-plasmonic information processing.

2. Theory and model of structures

We present three AOPS with the features of compact size, low input energy, and high transmission power. The coupling strength, the losses in the propagation, and the bend losses at the corners of structures are important factors in designing the AOPS. Square ring has a better coupling strength than circular ring, but the losses of square ring are more than circular ring. Considering these observations, we propose an octagon ring to make a tradeoff between

* Corresponding author.
E-mail addresses: m.ghadrdan@pgs.usb.ac.ir (M. Ghadrdan), mansouri@ece.usb.ac.ir (M.A. Mansouri-Birjandi).

https://doi.org/10.1016/j.photonics.2018.01.003
1569-4410/© 2018 Elsevier B.V. All rights reserved.

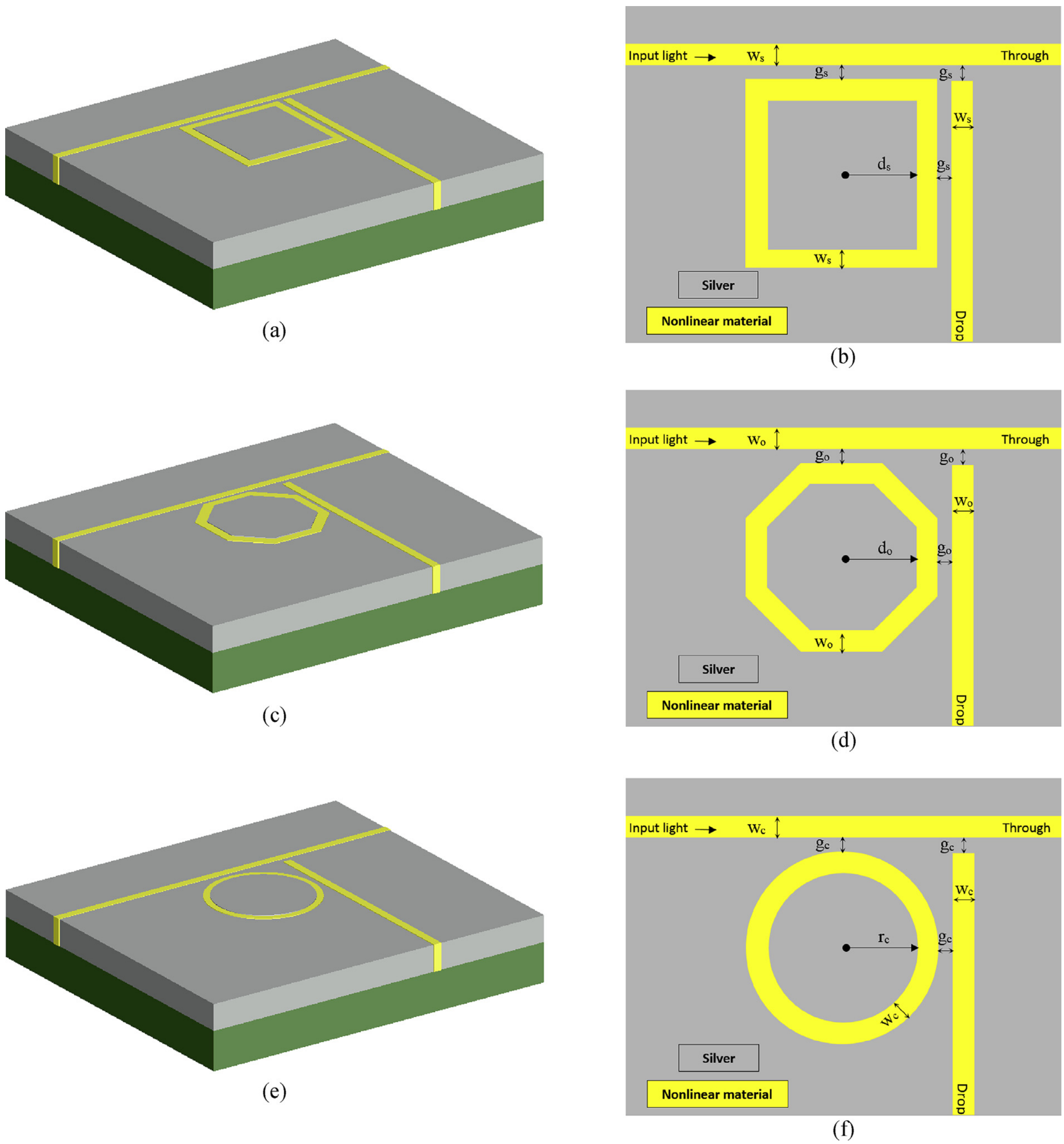

Fig. 1. The schematics of the proposed (a) square, (c) octagon and (e) circular AOPS. Top view of (b) square, (d) octagon and (f) circular AOPS.

circular and square rings. Fig. 1 presents the schematics of the proposed AOPS. Each of these three AOPS consists of a RR and two input and output waveguides with identical waveguide widths. We consider three different configurations of RRs, namely square, octagon and circular ones, which are shown in Fig. 1(a, b), (c, d) and (e, f), respectively. In metallic structures, only TM polarization excites the SPPs [39]. When a light with the TM polarization is lunched to the metallic structure, the incident light will excite the SPPs on metal interfaces. In addition, the TM polarization light at the resonant wavelength of the RRs will excite the SPPs in the RR. In all the three configurations, the metal is assumed to be silver with complex dielectric constant characterized by the Drude model [35]:

$$\varepsilon_m = \varepsilon_\infty - \omega_p^2 / \left(\omega^2 - j\gamma\omega\right) \tag{1}$$

where $\varepsilon_\circ$, ω, γ_p and ω_p are the relative permittivity at infinite frequency, the angular frequency of the incident lightwave, the electron collision frequency and the plasma frequency, respectively. The parameters taken from [35] and are the following: $\varepsilon_\infty = 1.95$, $\omega_p = 1.37 \times 10^{16}$ (rad/s), and $\gamma = 20 \times 10^{12}$ rad/s. In this case, we assume that the nonlinear material used, is Au/SiO_2 composite with high Kerr nonlinearity, which has the refractive index of n = 1.47 and its Kerr non-linear coefficient is $n_2 = 2.07 \times 10^{-9}$ cm^2/W [40]. The Au/SiO_2 composite is prepared by introducing small metal particles into SiO_2 glass. The surface plasmon resonance of metal particles can lead to enhanced third-order optical nonlinear susceptibility [41].

Ring resonator confines light within small volumes and resonates for light of specific wavelength that the round-trip phase shift is an integer multiple of 2π [42]. The resonant wavelengths of the ring are as follows [42]:

$$\lambda_r = L n_{eff} / m \tag{2}$$

Download English Version:

https://daneshyari.com/en/article/7932763

Download Persian Version:

https://daneshyari.com/article/7932763

Daneshyari.com