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Nonlinear Ring Resonator of Hybrid Plasmonic Waveguide

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ABSTRACT
A Plasmonic waveguide is based on the high mode confinement and low propagation loss compared with the other methodology of hybrid plasmonic waveguide. The concept of hybrid plasmonic waveguide is consists of a low index dielectric layer is inserted between a high index dielectric material and with a metal layer, so that the mode is largely confined within the low index layer. In this paper, address the use of Hybrid Plasmonic Waveguide for nonlinear application such as optical switching devices, with the nonlinear phenomenon known as Kerr effect. This Nonlinear Hybrid Plasmonic Waveguide(NLHPW) is modelled using the FEM(Finite Element Method) analysis and their performance of the Nonlinear Hybrid Plasmonic Waveguide has been investigated by using the figure of merit for measure the Kerr nonlinearity of the NLHPW. A good balance between mode confinement and loss of NLHPW has been shown. Relatively it has long propagation length of 30 to 60 um can be archived.

KEYWORDS: Hybrid Plasmonic Waveguide, Nonlinearity, Nano Photonics, Optical Switches.

INTRODUCTION

Nanophotonic of plasmonic waveguide structure is the recent technology in high speed and ultra-compact optical devices[1]. Plasmonic waveguide is used to guide the light in the Nanoscale region beyond the diffraction limit with strong node confinement but they have high propagation loss[2]. Even though, lot of geometries and structure are proposed for reducing the propagation loss. The recent method of plasmonic waveguide is based on the high mode confinement and low propagation loss compared with the other methodology of hybrid plasmonic waveguide[3].

The proposed geometry of nonlinear hybrid plasmonic waveguide is shown in below fig 1. The whole waveguide structure is covered with a dielectric material. The focus of the ElectroMagnetic field at the metal corners, which results from the pattering method of the metallic ridge layer. The materials that are used in designing the waveguide were chosen according to their abundance, their cost, their low optical loss, and their compatibility with current fabrication techniques[4]. For example, silicon and silica are abundant and used in the current integrated circuit technology. Metals such as gold, silver, and aluminum can be used because their plasma resonances are close to the visible light spectrum. In this study, silver is used as the thin metal film because the conductivity of silver is better than gold; therefore, using gold in waveguides increases the optical loss. The geometry of the hybrid plasmonic waveguides is designed as a rectangular waveguide in order to be compatible with SOI and CMOS technologies.

The loss and confinement of plasmonic waveguides represents a barrier to their practical use[5]. Normally, highly-confined plasmonic waveguide have short propagation lengths because of the mode attenuates quickly, therefore the optical signal switching cannot be archived. In addition that weakly-confined plasmonic waveguide have large propagation length but the intensity of the confined mode is weak so that the 2nd order-nonlinear interaction cannot be performed well because high optical intensity is required for the strong nonlinear interactions. For that it is essential to define a figure of merit that maximizes the kerr nonlinearity of the waveguide in order to optimize the structures of the nonlinear hybrid plasmonic waveguide.

I. Nonliner ring resonator:

A. Nonlinear Optical Waveguide:

Devices based on the Kerr effect can implement sub-picosecond optical switching [47]. The phase shift of a propagating mode in such switching devices will be studied in two cases: neglecting absorption loss and including absorption loss; The phase shift of a propagating mode in a lossless waveguide can be expressed as

$$\Phi=2\pi nL/\lambda \tag{1}$$

Where L is the waveguide length, λ is the wavelength of the propagating optical signal in the waveguide, and n is the material refractive index, which given by

$$n=n_0+n_2I \tag{2}$$

n_0 is the linear part of the refractive index, and n_2 is the second-order nonlinear index coefficient; this is a material property that measures the degree to which the material refractive index n changes with optical guided mode intensity I.

B. Effective index Analysis:

A Effective Index method is used to find the effective indices of the NLHPW. They have three analytical methods for finding the effective indices. First, we have to divide the waveguide structure into different regions, those regions can be treated as slab waveguide & then effective indices of the three regions can be formed. In that region of one and three has the same effective index value here as the effective index of the middle region id different. Lastly the effective indices of the whole region can be consider as core and cladding indices because to find the overall effective index of the geometry structure. Due to this geometry analysis, we use the eigen mode solver based on the FEM in the comsol multiphysics software in order to find the effective indices of the slabs of hybrid plasmonic waveguide.

II. Design Analysis:

A simple structure of a ring resonator device based on the NLHPW is shown in Fig 1. Where w is the core width, r is the ring radius, and d is the separation distance between the waveguide and the ring. If we input a signal of SPP modes into the straight waveguide (SWG), some of the modes will be coupled into the resonator and will experience multiple passes around then, this signal will interfere with the remaining SPP signal, constructively or destructively, depending on the ring circumference and its effective index, which can have a nonlinear shift. We are interested in studying the transmission characteristics of the device.

A good balance between mode confinement and propagation loss because they combine the strong confinement of plasmonic waveguides beyond diffraction limit and the long propagation length of dielectric slot waveguides. This advantage of HPWs makes them promising candidates for compact nonlinear devices that require a high degree of optical intensity with low power consumption and high switching speed

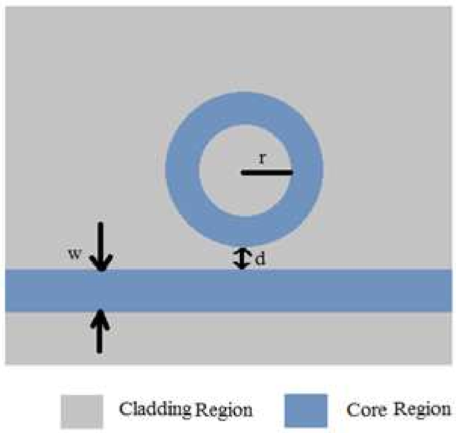

Fig. 1: A schematic diagram of the nonlinear ring resonator device.

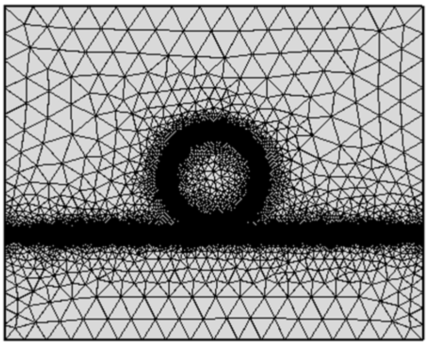

Fig. 2: Mesh analysis for the light propagating region of the nonlinear ring resonator.

In practical case, when we build a device on a chip, a few mW of optical power is required in order to operate it. These high input powers is not a problem for us because for optical switching we would use short pulsed laser, and we can switch beam in short duty cycle. That means the required *average* power to switch data is much lower than the actual switching beam power (peak power) by two or three orders of magnitude. Recent research has been conducted to investigate the use of HPWs for nonlinear applications. In this work, we are going to model a nonlinear hybrid plasmonic waveguide (NLHPW), study its Kerr nonlinearity, and model a ring resonator device based on the NLHPW.

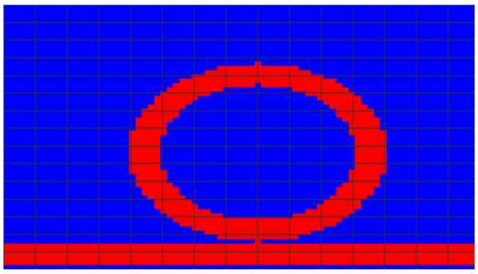

Fig. 3: Refractive index of the nonlinear ring resonator.

Refractive index of the NLHPW can be describe he linear way of propagation factor the ring resonator. Many nano-scale optical waveguides have been proposed based on the Kerr effect to study all-optical switching. For example, silicon nanowires have been shown to have high nonlinearity, but they are limited in size due to the diffraction limit. In addition, photonic crystal waveguides have been shown to have high nonlinearity with strong mode confinement but cannot be easily integrated on chips. Nonlinear dielectric slot waveguides, which confine light in a low-index nonlinear region between high index materials based on the discontinuity of normal electric field components at the interface, have shown a remarkable ability for all optical Kerr switching devices because the light can be confined beyond the diffraction limit in a direction perpendicular to the slot.

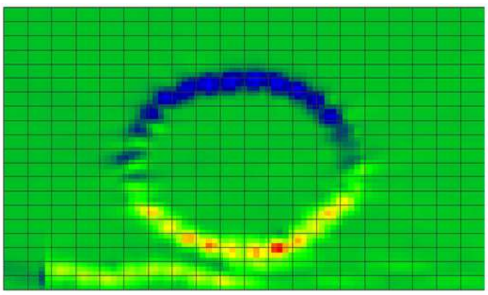

Fig. 4: A surface plot shows the power flow in the *x*-direction of the ring resonator device at the resonance, where the intensity in the ring is enhanced 4 times more than the input waveguide.

IV. Result Analysis:

A COMSOL software to adjust the geometric parameters of the ring resonator device such as W=200nm,d=250nm and r=1μm , and do a single frequency domain simulation at λ=1550nm by launching a input power 1mW We find that the resonance condition is satisfied at approximately 1.55µm , and the field intensity inside the ring is enhanced 4 times higher than the intensity in the input waveguide. This enhancement of the field intensity in the ring resonator makes it a candidate for nonlinear optical applications, which require a high optical field intensity to perform nonlinear interactions, such as optical switching devices.

Below graph shows the transmission spectrum of the resonator; it illustrates how the nonlinear ring resonator permits transmission a range of wavelength through the output of the waveguide except at two wavelengths, which satisfy the resonance conditions in the ring; The power of the input signal can affect transmission of the device, resulting in a nonlinear resonance shift. For example, if we input a power=300 mW into the input waveguide. where the effective mode area of our NLHPW is approximately $A_{eff}=0.05\mu m^2$ the signal intensity will be $I=6x10^{12}$ W/m^2 the data signal intensity will lead to change the core index of the input waveguide.

The change in the ring core index is more than that of input waveguide because of the enhancement of the transmitted field in the ring more than in the input waveguide by a factor ¬4. This nonlinear index shift in the core indices will affect the critical coupling between the waveguide and the ring so that the resonance peak and its transmission will be shifted.

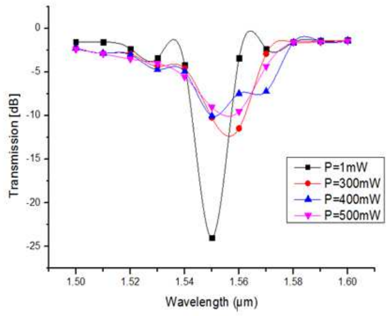

Fig. 5: The nonlinear resonance shift of the ring resonator transmission for different input powers.

V. Conclusion:

A Plasmonic waveguide is based on the high mode confinement and low propagation loss compared with the other methodology of hybrid plasmonic waveguide. The enhancement of the field intensity in the ring was four times higher than the field intensity in the input waveguide. In addition, the effect of using different input power on the signal transmission resulted in a nonlinear resonance shift of the resonance peak. A nonlinear ring resonator device based on the NLHPW was modeled and analyzed theoretically. Therefore, an ultra-fast all optical switching device based on the NLHPW will have potential use in nanophotonic integrated circuits to process data in the optical domain.

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REFERENCES

1. Ozbay, E., 2006. “Plasmonics: Merging Photonics and Electronics at Nanoscale Dimensions,” Science, 311: 189-193.
2. Vlasov, Y.A. and S.J. Mcnab, 2004. “Losses in single-mode silicon-on-insulator strip wave guides and bends,”Opt. Express, 12(8): 1622-1631.
3. Suhir, E., 2000. “Microelectronics and photonics: the future,” Microelectr J, 31: 839-951.
4. Brongersma, M.L. and V.M. Shalaev, 2010. “The Case for Plasmonics,” Science, 328(5977): 440-441.
5. Maier, S.A. and H.A. Atwater, 2005. “Plasmonic: localization and guiding of electromagnetic energy in metal/dielectric structures,” J. Appl. Phys., 98: 011101.
6. Barnes, W.L., A. Dereux and T.W. Ebbesen, 2003. “Surface Plasmon subwavelength optics,”Nature, 424: 824-830.

7. Worthing, P.T. and W.L. Barnes, 2001. “Efficient coupling of surface plasmon polaritons to radiation using a bigrating,” Appl. Phys. Lett., 79(19): 3035-3037.
8. Oulton, R.F., V.J. Sorger, D.A. Genov, D.F.P. Pile and X. Zhang, 2008. “A hybrid plasmonic waveguide for subwavelength confinement and long-range propagation,”Nat. Photonics, 2: 496-500.
9. Alam, M.Z., J. Meier, J.S. Aitchison and M. Mojahedi, 2010. “Propagationcharacteristics of hybrid modes supported by metal-low-highindexwaveguidesandbends,”Opt. Express, 18(12): 12971-12979.
10. Dai, D. and S. He, 2010. “Low-loss hybrid plasmonic waveguide with double low-index nano-slots,”Opt.Express, 18(17): 17958-17966.
11. Muellner, P., M. Wellenzohn and R. Hainberger, 2009. “Nonlinearity of optimized silicon photonicslotwaveguides”,Opt.Express, 17(11): 9282-9287.
12. Wolchover, N.A., 2007. “High nonlinearity glass photonic crystal nanowires,” Opt. Express, 15(3): 829-833.
13. Davoyan, R., I.V. Shadrivov and Y.S. Kivshar, 2008. “Nonlinear plasmonic slot waveguides,” Opt. Express, 16(26): 21209-21212.