Low-Cross-Talk Metal-Dielectric-Metal Waveguide Intersections Based on Sodium

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Abstract- **We analyzed the transmission properties of two plasmonic waveguides crossing by using numerical simulations. The subwavelength width waveguides are composed of sodium-air-sodium. The crossing structure is composed by a compact cross-shaped resonant cavity with a four-fold symmetry. The results demonstrated the feasibility of using sodium as a low loss material for several applications for nanoplasmonic integrated circuits implementation.**

I. INTRODUCTION

Plasmonic waveguides and plasmonic devices are under investigation because it allows light confinement in subwavelength scale regions, with relatively low losses and they are good candidates for a myriad of high density integrating applications in optical communications and biological sensors. Commonly, gold and silver are the most used materials for the design and fabrication of plasmonic waveguides and devices due to their low losses in the visible and near-infrared (NIR) as well as their chemical stability. However, several other low-loss non-noble materials are under study to compete against gold and silver [1-6].

Recently, sodium has attracted attention because of its low cost and also low losses with surface plasmon propagation distances of several wavelengths [5,6]. High integration plasmonic devices should allow the intersection of several waveguides where high transmission and low crosstalk are necessary in order to increase the circuit performance with low interference.

In this work, we analyzed the crossing of two perpendicular plasmonic sodium-air-sodium waveguides where the crossing region is based on a compact resonant cavity, initially designed for silver-air-silver waveguides [7]. High transmission can be obtained near their resonant wavelength with low interference and low crosstalk in the NIR frequencies.

II. MATERIALS, METHODS, AND RESULTS

The complex refractive index of silver [8] (one of most used plasmonic material) and sodium [9] are shown in Fig. 1. It can be observed that both of them exhibit similar and low refractive indexes in the NIR while sodium has lower extinction coefficient than silver, thus, lower losses can be expected by using sodium as plasmonic material.

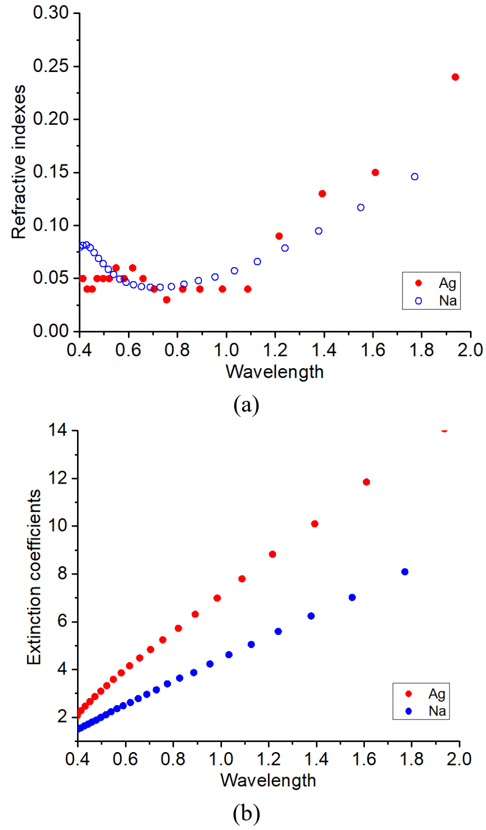

Fig. 1. Complex refractive indexes of silver [8] and sodium [9]. (a) Refractive indexes. (b) Extinction coefficients.

We analyzed the transmittance through intersections of plasmonic waveguides, as shown in Fig. 2, coupled by a cross-shaped cavity [7]. The plasmonic waveguides are comprised of metal-dielectric-metal (MDM). The cavity exhibits a resonant mode at a resonant frequency determined mainly by its size [7], and when it is coupled to one or more waveguides, the electromagnetic fields of the resonant mode can leak into them by tunneling effect. The MDM waveguides have core of 50 nm. The input and output waveguides are 150 nm apart from each other. The cross-shaped cavity is located at the center of the geometry, and its arms with 220 nm length are rotated 45 degrees in relation to the waveguides [7]. The numerical results are calculated by a commercial solver [10] based on finite element method in frequency domain.

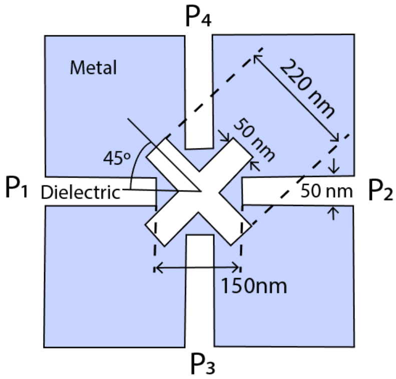

Fig. 2. MDM intersection configuration for low-cross-talk [7].

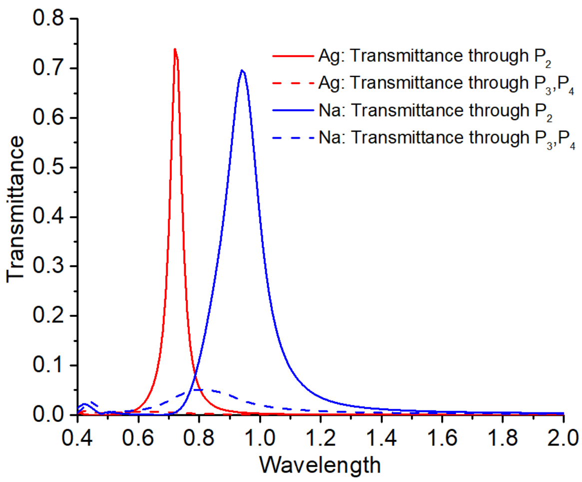

Fig. 3. Transmittance spectra of MDM component shown in Fig. 2, from P_1 through the output port P_2 and ports P_3 and P_4. The transmittance consider metal comprised of silver or sodium and dielectric comprised of air.

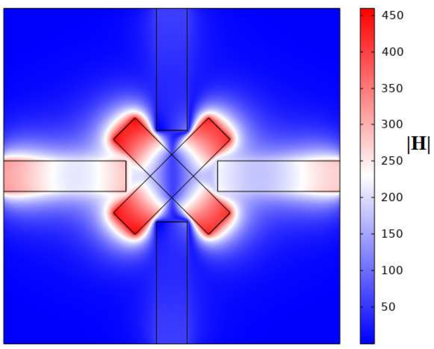

Fig. 4. Absolute value of the magnetic field |H| distribution through the intersections at resonance when using sodium in metal region.

The transmission of the analyzed crossing is shown in Fig. 3. The sodium based system exhibits a higher resonant frequency than sodium and it occurs at about 940 nm. Additionally, the transmission is sligthly lower than the one of the silver with a broad bandwidth. The magnetic field distribution at the resonant frequency is shown in Fig. 4. It can be observed the coupling of the energy from the left to the right waveguide with low cross talk to the vertical ones.

III. Conclusion

In summary, a low-cross-talk sodium-air-sodium waveguide intersection based on a cross-shaped cavity was analyzed by using frequency domain finite element method. It was shown a high transmittance and low footprint. The relatively high transmission and negligible crosstalk occurs around the cavity resonant wavelength. Sodium based waveguides and crossings could be great helpful for high-density integration. Without considering the material loss, the throughput can be almost the unity on resonance and the crosstalk could be suppressed.

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