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Unidirectional Optical Interconnects based on Gap Plasmon Resonators

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Abstract:

Disruptive grating couplers based on plasmonic resonators deposited on the surface of photonic waveguides are considered for the unidirectional excitation of guided modes at normal incidence. A Fourier Modal Method is used to study the absorption of the gratings and evaluate the coupling efficiency of light in the waveguide.

Keywords: Plasmonics; Grating Couplers; Optical Interconnects, Gap Plasmon Polariton, Gap Plasmon Resonator

DOI:

1. INTRODUCTION

Grating couplers are the most versatile mechanism to couple light efficiently into waveguides featuring submicronic cross-sections. Most often, grating couplers are used in a tilted illumination configuration in such a way that the power scattered by the grating is dominantly sustained by a single diffraction order leading to unidirectional excitation of the waveguide.

In practical applications, tilted illumination of the gratings is not always possible in particular for fully integrated opto-electronic PCBs with a light source and an optical layer implanted on each side of the board. In this case, the incoming light hits the gratings couplers at normal incidence and specific strategies mostly based on reflectors are needed to achieve unidirectional excitation of the guided mode.

Many strategies to obtain unidirectional grating couplers have been demonstrated in silicon photonics, most of them employing a reflecting structure on one side intended for reflecting back the mode traveling in the undesired direction. The reflecting structure can be as simple as a single trench [1] or a more complex Bragg reflector [2].

In this work, a novel unidirectional optical interconnect concept based on the use of gap plasmon polariton (GPR) grating couplers sustained by Metal-Insulator-Metal (MIM) resonators is introduced. Unlike traditional challenging subwavelength coupling schemes based on plasmonics and Si-Photonics, we consider non-symmetric GPR featuring highly directional scattering efficiency.

2. 2. FOURIER MODAL METHOD ANALYSIS

Gap plasmon polariton (GPP) modes are typically sustained by Metal/Insulator/Metal (MIM) stacks. For sufficiently thin insulator gaps, the interface surface plasmon mode supported by each Metal / Insulator interfaces hybridize to generate GPP featuring high phase constant and relatively long propagation 1/e damping distances. Finite width MIM stacks support

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localized resonances originating from the efficient reflection of the GPP mode onto the boundaries of the finite width stacks [3,4].

For a fixed free-space wavelength, two consecutives resonances of a given finite width MIM stacks denoted GPR gratings occur for widths separated roughly by half a wavelength of the GPP mode supported by the corresponding infinitely wide stack [5,6].

We consider a MIM stack(see Figure 1) comprised of two 50nm-thick gold films separated by a gap of 20nm embedded into a homogeneous silica medium.

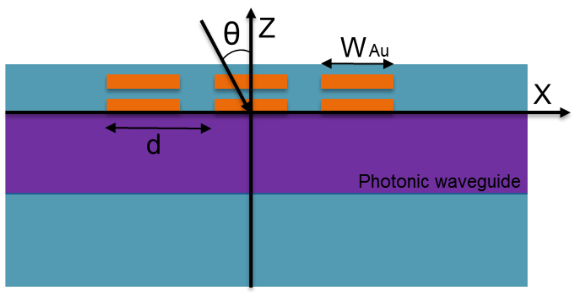

Figure 1. Diagrammatic view of the GPR grating of period d and width of the resonators Wau considered for the FMM analysis.

At a frequency corresponding to a free-space wavelength λ=1.55µm we find by means of the reflection pole method that the GPP mode of interest has an effective index of n_{eff}=2.70 and a damping distance LGPP=2.2µm. A numerical simulation (Fourier Modal Method) was developed in order to compute the absorption of the waveguide. For the structure shown in Figure 1 we find that at a wavelength of 1.55um and period d=850nm, the zero order is the only scattered order making this configuration convenient for the characterization of the individual GPR resonances.

3. RESULTS and DISCUSSION

Figure 2 displays the absorption of the waveguide computed with the Fourier Modal Method using up to 203 harmonics in the Floquet's expansion of the electromagnetic field generated by the plane wave excitation of the grating. For a grating period d=800nm and W_{Au} ranging from 50nm to 450nm, we can observe absorption peaks dependent on the angle of incidence of the incident beam around W_{Au}=250nm and W_{Au}=320nm corresponding to two consecutive resonances of the GPR.

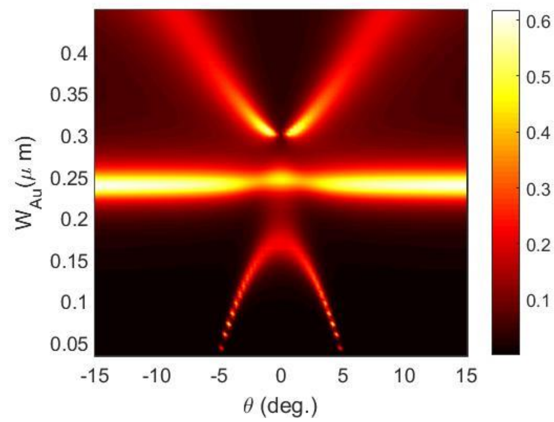

Figure 2. Absorption of the waveguide decorated with GPR grating couplers computed at λ=1.55um for different grating width and angle of incidence (fixed grating period).

We note also that the absorption peak for the first resonance is observed whatever the angle of incidence whereas the higher order resonance cannot be excited with a plane wave normally incident onto the grating as a result of the odd symmetry of the field distribution of this resonance.

The GPR resonator decorated waveguides have been analyzed so far on the basis of their optical properties under plane wave excitation using the Fourier Modal method.

Following this analysis we now focus on a local excitation of the corrugated waveguides using a Gaussian beam to determine the characteristics of the optimum GPR gratings for an efficient unidirectional excitation of the waveguide mode when excited at normal incidence.

We first consider a two-dimensional TM polarized Gaussian beam falling at normal incidence onto the bare waveguide. Figure 3 (top) and Figure 3 (bottom) show respectively the electric field modulus and the x-component of the average Poynting Vector Sx. The result of the integration of the Sx is basically the power carried by the beam in the x-direction is normalized with respect to the power of the incident beam, having for this particular structure a maximum coupling efficiency of 30%.

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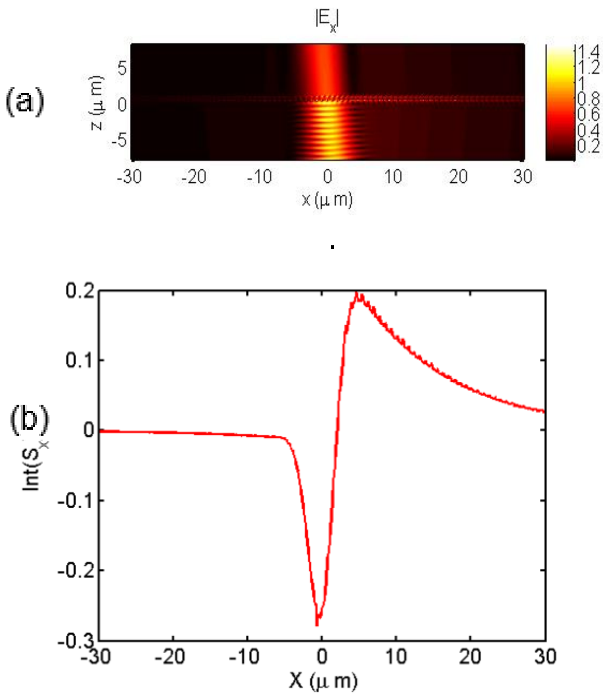

Figure 3. a. Modulus of the electric field for a Gaussian beam with a 3.0μm-waist shining at normal incidence the bare photonic waveguide. **b.** Integral of the Poynting Vector Sx component along the z-direction.

4. CONCLUSION

We have introduced a disruptive approach for unidirectional coupling at normal incidence into waveguide modes using broken-symmetry gap plasmon resonators. The grating couplers we have proposed rely on the strong coupling between the local resonances sustained by the GPR resonances and the Bloch modes supported by the decorated waveguides. We have seen that for a carefully adjusted period of the grating, the local GPR resonance excited directly by the incident field and the waveguide mode coupled in by the grating can interfere constructively at one angle of incidence and destructively for the opposite angle.

5. ACKNOWLEDGMENT

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