Nano Scale Disruptive Silicon-Plasmonic Platform for Chip-to-Chip Interconnection

Decision on optimized plasmonic waveguide couplers

Milestone no.: M25
Due date: 04/30/2012
Actual Submission date: 04/30/2012
Authors: KIT
Work package(s): WP5
Distribution level: RE[1] (NAVOLCHI Consortium)
Nature: document, available online in the restricted area of the NAVOLCHI webpage

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Executive Summary

This document shall incorporate (all) rules procedures concerning the technical and administrative management of the project and is therefore to be updated on a regular basis. Please look at www.navolchi.eu regularly for the latest version.

Change Records

Version	**Date**	**Changes**	**Author**
0.1 (draft)	04/10/2012	Start	Argishti Melikyan
1 (submission)	04/30/2012		Argishti Melikyan

Introduction

Referring to the decision made on plasmonic modulator design, efficient couplers are necessary which will provide good coupling between the low loss silicon nanowire waveguide and the plasmonic vertical slot waveguide, see Fig. 1. Moreover, from NAVOLCHI milestone "*Decision on an optimized structure for plasmonic modulator*" can be seen that the figure of merit of the modulator increases with reducing the size of the plasmonic slot. Such aggressive downscaling of the plasmonic slot makes the SPP excitation even more challenging because of the strong dimension mismatch between silicon nanowire and plasmonic slot waveguides.

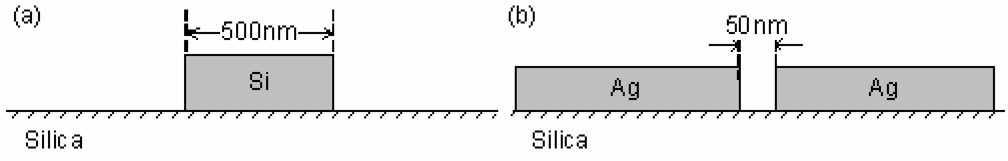

Figure 1 Typical waveguides used in (a) silicon photonics and (b) in active plasmonics.

The most promising approach to couple light from a silicon nanowire to a plasmonic slot waveguide is the tapered metallic coupling configuration which provides very large and broadband coupling efficiency[2]. In such a coupling scheme, quasi-TE polarized light guided through silicon nanowire is adiabatically squeezed and launched into the plasmonic slot waveguide, see Fig. 2(a).

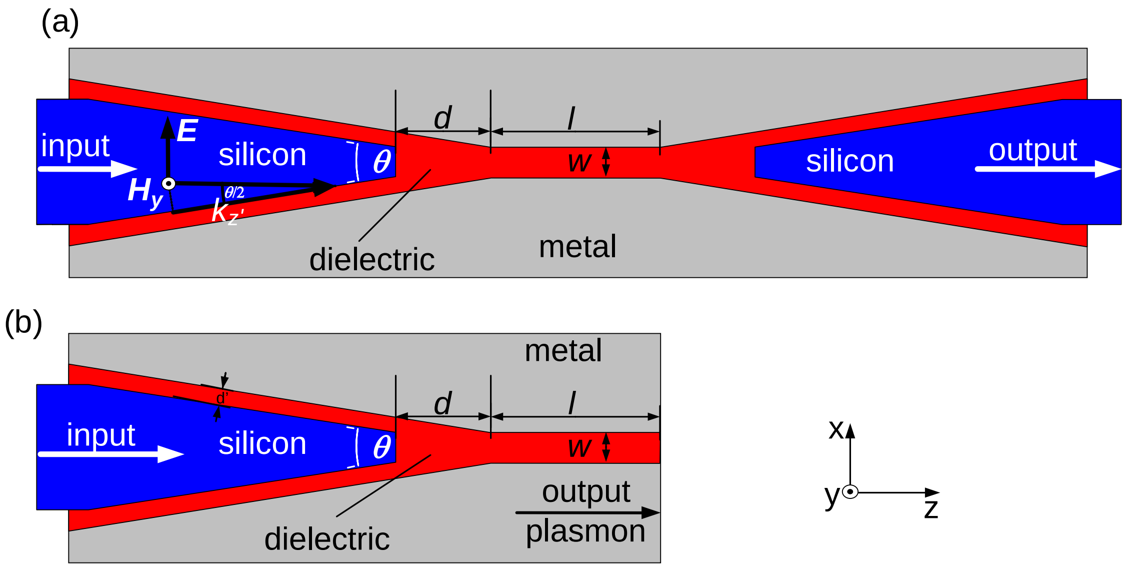

Figure 2 Geometry of plasmonic coupler, (a) top view of the realistic plasmonic modulator with two coupling sections and (b) structure used in optimization

The coupler is optimized for its highest transmission for the given silicon width of 500nm, dielectric material with a refractive index of 1.6. The realistic plasmonic modulator consists of two coupling sections for in- and out-coupling of the active region with a length of *l* as it is

[2] Sh. Zhu, T. Y. Liow, G. Q. Lo, and D. L. Kwong, "Silicon-based horizontal nanoplasmonic slot waveguides for on-chip integration," Opt. Express **19**, 8888-8902 (2011)

depicted in Fig. 2(a). However, because of the limitation of the computational power, we have restricted ourselves in optimizing a single coupling section as the structure is symmetric relative to the central active section.

Methods and Results

To calculate the SPP excitation efficiency we have performed simulation of the propagation of electromagnetic wave based on the Finite Integration Technique (CST Microwave Studio). To avoid from additional complexities in the computational, first the simulations have be carried out for 2D structure i.e. no refractive index variation along *y*-axis. The excitation efficiency of SPP in the metal-dielectric-metal structure is calculated as normalized transmission coefficient from the silicon waveguide to the plasmonic waveguide

$$transmission = \frac{P_{out}}{P_{in}} \tag{1.1}$$

where the P_{in} is the power at the input of the silicon waveguide and P_{out} the power at the output of the plasmonic waveguide, see Fig. 2(b). The *transmission* is calculated varying the angle of the silicon tip θ, separation of plasmonic and silicon waveguides d. This is done for various plasmonic slot widths and dielectric refractive indices. The results of the refractive index of 1.6 are summarized in Fig. 3.

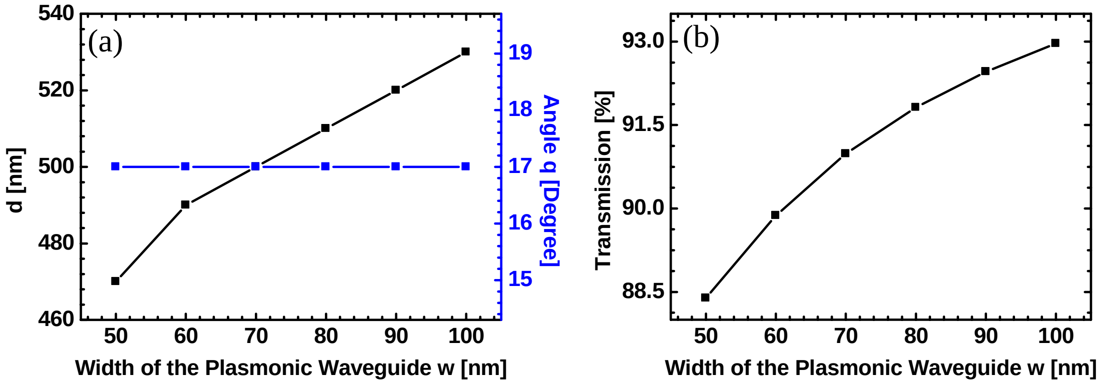

Figure 3 The optimized couplers geometry for various plasmonic waveguide widths *w*. (a) Optimized silicon tip angle θ and distance *d*. (b) Transmission corresponding to optimized structure

It can be seen that the coupler provides the maximum coupling efficiency for the certain silicon tip angle of 17 degrees. Slight dependence of the optimum distance *d* on plasmonic waveguide width *w* can be seen. In all the cases the normalized transmission exceeds 85%, see Fig. 3(b), which makes such approach of SPP excitation unique.

The results have been confirmed for 3D realistic coupler with the metal and silicon heights of 220nm. In Fig. 4 we show the typical field propagation in the coupler in the terms of magnetic H_y and electric E_y fields.

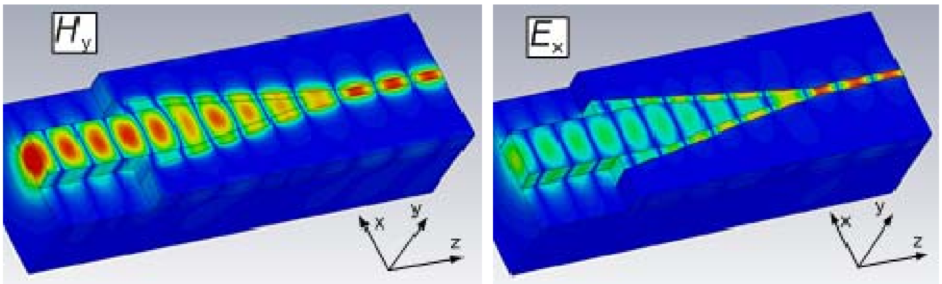

Figure 4 H_y and E_x component of the electromagnetic wave propagating through the plasmonic coupler (3D).

An example of the geometrical parameters of the 3D realistic coupler can be found in Table 1.

Table 1 The geometrical parameters of the coupler for 50nm plasmonic slot width

SOI device layer thickness	220nm
Silicon waveguide width	500nm
Plasmonic slot width	50nm
Distance *d*	75nm
Angle θ	36°
Efficiency of a single coupler	**87%**