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Optimization of silicon wire waveguide crossing by means of vertical coupling with a polymer waveguide

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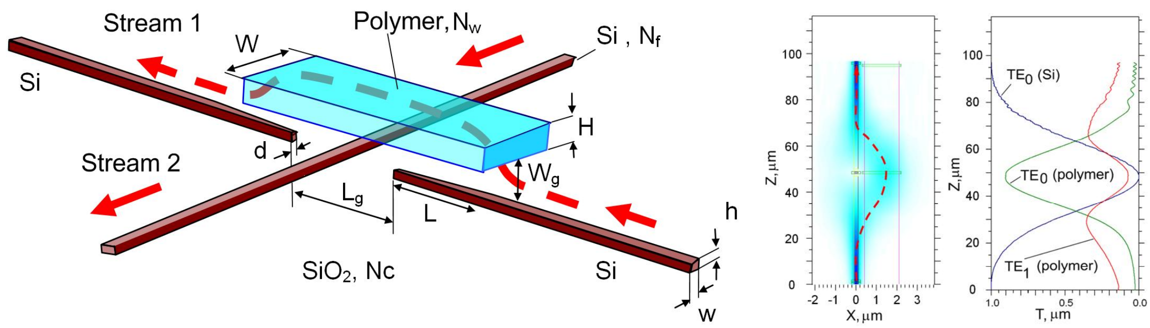
Abstract: We analyze the excellent waveguide crossing by making the optical beam to pass over the intersecting silicon wire waveguide by means of vertical up and down coupling through the silica buffer of tapered Si wires with the upper low index strip waveguide. We complete the optimization procedure by combination different methods (BPM, MoL, FDTD) which make possible to find such combinations of parameters of structure which provide (in the 35 nm spectral interval in a telecommunication range 1.55 μm) the high efficiency of crossing (98 % and above), simultaneously, for direct transmitting (the Stream 1) and a cross direction (the Stream 2), having any number (from 1 to 1024) of similar crossings.

Introduction

It is known that a good solution for the problem of cross-scattering is arranging the waveguide crossing in different spatial layers. For example, an efficient crossing has been realized in high-contrast silicon wires on the base of tunnel coupling of two vertically overlapped inverse tapers. Practical realization of the given decision requires the polysilicon [1] or silicon nitride [2] deposited technology and precision manufacturing of two oppositely directed tapers located in different layers one under the other in the strict position along the optical pass. In this paper we discuss and make optimization of alternative and much simpler structure [3-5] based on the vertical coupling of a Si wire taper with the upper low index straight polymer waveguide through the silica buffer (see Fig. 1).

Multi layer waveguide crossing

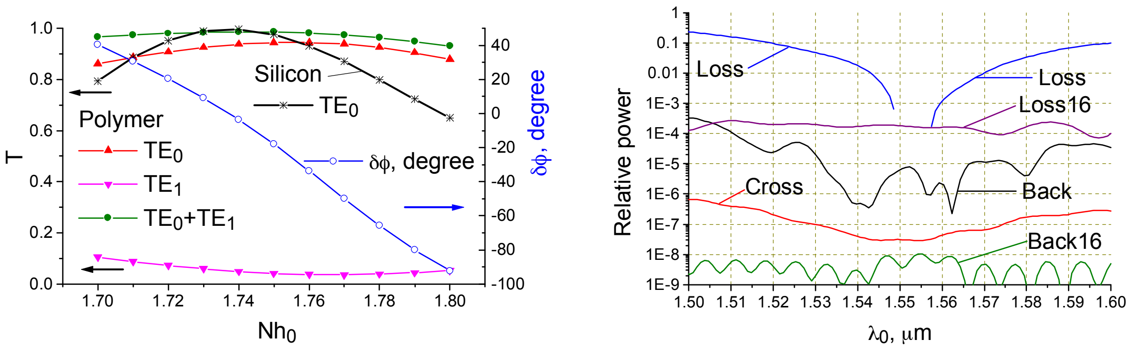
The analysis of wire crossing is executed in separate parts which are studied by different methodological approaches. Because of a great number of independent parameters (*d, h, w, H, W, L, Lg, Nw, Nf, Nc*), each of which can bring the essential contribution to the transmitting efficiency of light through a crossing area, we accomplish initial analysis by the 2D models (BPM and MoL) under effective index method (EIM) [6] approximation. Three-dimensional modeling by 3D FDTD, in all senses consuming on resources, is applied as intermediate check and at a stage of definitive testing.



a) *b)* *c)*

Fig. 1. The effective crossing of two silicon wires. The basic scheme (a); Cross-section of an electromagnetic field calculated by 2D BPM method (b); Eenergy distribution between modes along an axis of the Stream 1 (c). Lg =3 μm, H = 1.7 μm, Wg = 80 nm, L = 45 μm, Nw = 1.56, Nh = 2.95, Nh0 = 1.76, Nc=1.4, h = 220 nm, Wg = 280 nm.

The algorithm of search of optimum parameters of wire crossing is arranged by the following procedure. By the fast algorithm of 2D beam propagation method (BPM) there are determined the parameters of optimum two-dimensional structure for the Stream 1 (see Fig.1(a)). Namely, for a set of values L and Wg we find optimum value of the EIM cores index (Nh0) in a 2D waveguide (see Fig. 2 (a)). Then the further three-dimensional parameter optimization is completed by 3D FDTD starting by variation of *d*, and then by change of *Wg* (for already determined optimum value *d*). In parallel we analyze power transmitting for the Stream 2 (see Fig.1(a)) in two dimensional case by the method of lines (MoL) for an arbitrary number of crossings (from 1 till 1024) and by 3D FDTD (up to 16 crossings). As a results the joint analysis of a task in view of different methods (BPM, MoL, FDTD) has allowed to find such combinations of parameters of structure which provide (in the 35 nm spectral interval in a telecommunication range 1.55 μm, see Fig. 2(b)) the high efficiency of crossing (98 % and above), simultaneously, for direct transmitting (the Stream 1) and a cross direction (the Stream 2), having any number (from 1 to 1024) of similar crossings and a negligible cross (-70 dB) and back (-50 dB) scattering.



a) *b)*

Fig. 2. Optimization of wire crossings. The relative transmitting power T carried out by different modes of both waveguides (the left scale), and also a difference of phases δφ *(the right scale) between the two first modes of a thick polymeric waveguide, as function of core index Nh0 for Wg = 180 nm in the area of crossing simulated by 2D BPM method (a); Dependence on working optical wavelength of the relative power transferred by a* TE_0 *mode for various streams for Wg = 340 nm, simulated by 3D FDTD(b). Loss = 1-T1(single crossing of Stream 1), Loss16=1-T16 (corresponds to 16 crossing of Stream 2), Lg =3* µ*m, H = 1.7* µ*m, W = 1.5* µ*m, L = 45* µ*m, Nf = 3.447, Nw = 1.56, Nh = 2.95, Nc=1.4, Nf = 3.447, Nw = 1.56, Nh = 3.0, Nh0 = 1.56, Nc=1.4, h = 220 nm, w = 450 nm, d = 180 nm.*

Conclusion

The excellent waveguide crossing by making the optical beam to pass over the intersecting silicon wire waveguide is numerically investigated in the paper. It is realized by means of vertical up and down coupling through the silica buffer of tapered thin high index Si wires with the upper thick low index polymer strip waveguide constructed by SU-8. The optimum device provides a low loss transmitting of light in both cross direction and negligible parasitic scattering.
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