OPTOELECTRONICS AND ADVANCED MATERIALS – RAPID COMMUNICATIONS Vol. 5, No. 7, July 2011, p. 715 - 717

Numerical computations of the electric field density in SOI structures

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In this paper we numerically compute the electric field density in SOI structures, for different distances between the silicon plates. Results show the more distant are the plates, the more is the difference in the electric field density, and the more is the distance between their maxima. Also, we can observe that light propagation in the SOI structure shows a much higher intensity than that achievable with conventional ways.

(Received July 5, 2011; accepted July 25, 2011)

Keywords: SOI, Electric field density

1. Introduction

Silicon on Insulator (SOI) substrates are being increasingly used in MEMS applications, with the insulating layers serving as etch stop/sacrificial layers and/or device function layers. Silicon photonics has emerged as a promising solution for electronic photonic integration [1,2]. Several electronic photonic integrated devices have been demonstrated including GHz modulators [3], switches [4], detectors [5] and transceivers [6]. Ravariu et al [7] present some techniques on SOI structures. Hence, it is of great interest to obtain information about the distribution of the electric field in the SOI structure. In this paper, we compute the time-avaraged electric-field energy density (hereafter dpwr = $\varepsilon|E|^2$) for a SOI structure consisting on two different parallelipipedes of high refractive index (silicon) $n_H = 3.48$, separated by a low index region (insulator) with $n_L = 1.44$. All the results were obtained by numerical simulations. In this scope, the free available numerical source MPB developed by Joannopoulos et al. was used [8].

2. Methodology

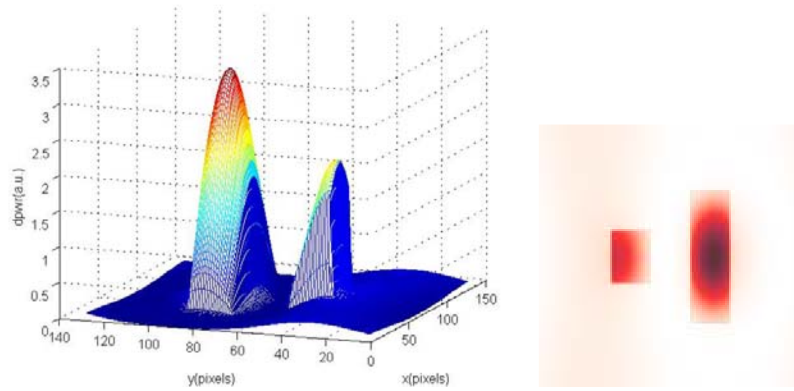
The SOI structure consists on two parallelipipedes of dimensions (1.2×2.×4.) *μm* and (1.2×4.×4.) *μm*, on silicon with refractive index of $n_H = 3.48$. The insulator has a refractive index of $n_L = 1.44$, and its width was varied, taking the values of 0.15, 0.18, 0.22 and 0.3 *μm*.

Note that the origin is situated at the low left corner of the smaller parallelipiped, the Ox axis points upward, and the Oy axis points rightward.

The source of the electromagnetic field has the form: $E(x,t) = A(x)B\exp(i\omega t)$, with $A(x) = 1$ and $\omega = 2\pi c/\lambda$, $\lambda = 1.55\mu m$.

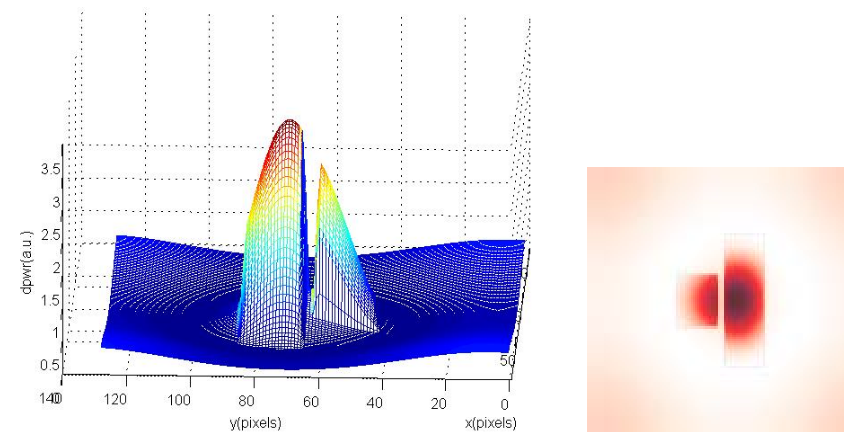
3. Results and discussion

Four runs were performed (not all shown), for *ws* = 0.15, 0.18, 0.22 and 0.3 *μm* in order to compute the dpwr distribution in the SOI structure. The plane wave expansion method was used. Results are shown in Figs. 1-3. The light leakage into the substrate, relying on external reflections provided by interference effects at a high – index contrast interface, results to be greater in the greater parallelipiped, especially for *ws = 0.3 μm* and *ws = 0.18 μm* (see Figs. 1 a, b and 2 a, b). They show high confinement of the light into the silicon. The same can be seen from Figs. 3 a, b, but in this case the dpwrs are comparable.



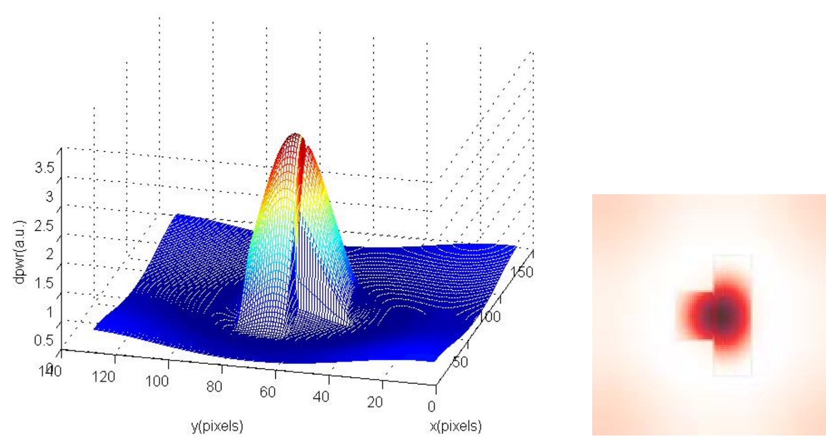
a b

Fig. 1. a) The dpwr distribution (arbitrary units) in the SOI structure for ws = 0.3 µm; b): Top view of the dpwr in the SOI structure.



a b

Fig. 2. a) The dpwr distribution (arbitrary units) in the SOI structure for ws = 0.18 µm; b): Top view of the dpwr in the SOI structure.



a b

Fig. 3. a) The dpwr distribution (arbitrary units) in the SOI structure for ws = 0.15 µm; b): Top view of the dpwr in the SOI structure.

Results show the more distant are the plates, the more is the difference in the electric field density, and the more is the distance between their maxima. We observe from Fig. 1 that for *ws* = 0.3 *μm*, the dpwr in the first slot is about 3.5 (a.u), whereas in the second slot is only 2. Likewise, they are about 10 pixels apart. For *ws* = 0.18 *μm* (Fig. 2), the dpwr maxima approach each other, as from the point of view of amplitude (3.5 and 3 respectivelly) as from the distance between them (several pixels). For *ws* = 0.15 *μm* (Fig. 3), the maxima are almost equal to 3.5 and tied together. Light propagation in the SOI structure shows a much higher intensity than that achievable with conventional ways. The vertical confinement of the *E*-field in the silicon is dictated by that in the insulator region. In conclusion, we have shown by numerical experiments that light is confined in the silicon.

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