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ELECTRIC FIELD IN VOID NANOSTRUCTURES

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Abstract. In recent years very much interest is devoted to void nanostructures. In this paper we perform numerical simulations in order to compute the time – averages of electric field E in a configuration of two slabs with high refractive index separated by air. Computations are performed for three different distances between the slabs. Results show that for all cases the time averages of electric field are smaller in the air separating the slabs, and greater in the slabs.

Key words: void structures, numerical simulations.

The subject of void structures is no more that two decades old. For a high – index contrast interface, Maxwell's equations state that to satisfy the continuity of electric flux density D, the corresponding electric field E must undergo a large discontinuity.

In 2009, Suresh Sridaran and Sunil A. Bhave [1] demonstrate a silicon photonic platform using thin buried oxide silicon-on-insulator (SOI) substrates using localized substrate removal. They show high confinement silicon strip waveguides, micro-ring resonators and nanotapers using this technology. Qianfan Xu *et al.* [2] experimentally demonstrate a novel silicon waveguide structure for guiding and confining light in nanometer-wide low-refractive-index material. The optical field in the low-index material is enhanced because of the discontinuity of the electric field at high-index-contrast interfaces. V.R. Almeida *et al.* [3] present a novel waveguide geometry for confining light in a nanometer-wide low-index material. Ciobanu *et al.* [4] presents a void structure that confine light in low-index region.

In this paper, we show that the optical field is enhanced and confined in the high-index material when light is guided by total internal reflection (TIR). To this aim, we compute by numerical simulations the averages of electric field for a configuration of two slabs, and for three different distances w_s between them. In this scope, the free available numerical code developed by Joannopoulos was used [5]. The results obtained in this work show that in each case the electric field E is smaller in the low-index region.

The chosen configuration consisted on two identical parallelipipedic high index slabs, of dimensions 100×20×15 nm (Fig. 1), separated by air; both slabs have the same refractive index $n_H = 3.4$. The distances between the slabs were considered equal to 15, 20, and 25 nm respectively. In each case, the electric field was computed and displayed.

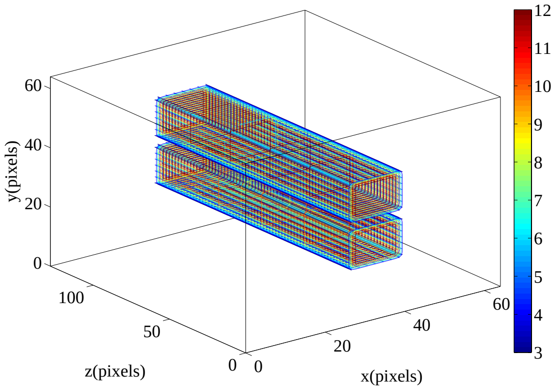

Fig. 1 – The arrangement of the slabs.

The source of the electromagnetic field has the form:

$E(x,t) = A(x)B\exp(\mathrm{i}\omega t)$, with $A(x) = 1$ and $\omega = 2\pi c/\lambda$, $\lambda = 1.55\mu\mathrm{m}$. The Maxwell equations were integrated using the Finite Difference Time Domain (FDTD) method.

We represent below the time – averages of electric field, for different distances of the distance between slots, w_s, in Fig. 2(a,b,c).

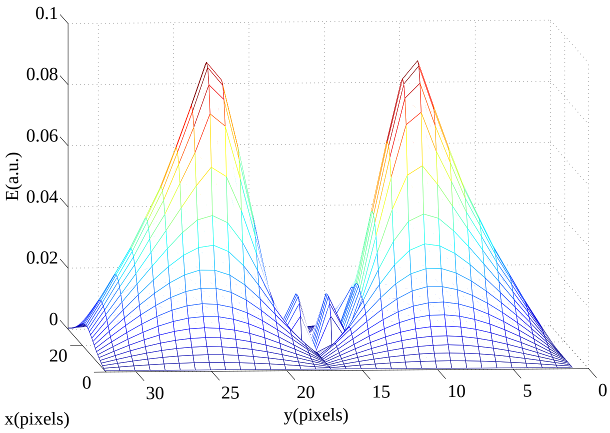

Fig. 2a – Time-averaged electric-field energy density for w_s =15 nm (arbitrary units).

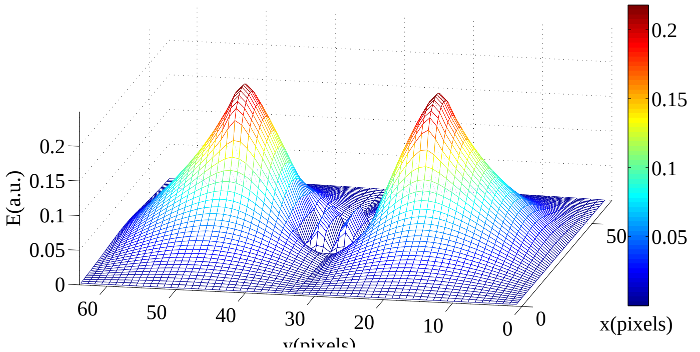

Fig. 2b – Time-averaged electric-field energy density for w_s =20 nm (arbitrary units).

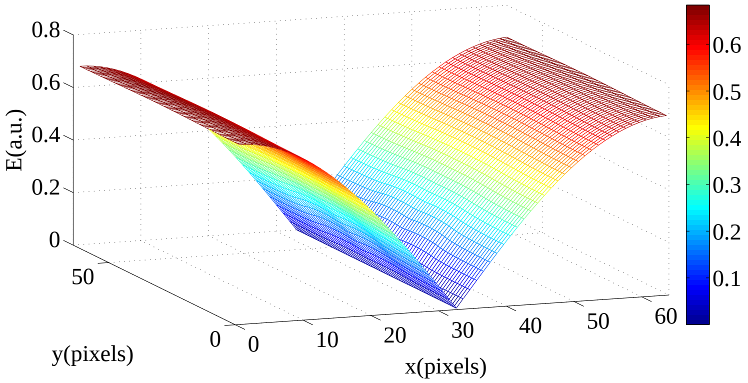

Fig. 2c – Time-averaged electric-field energy density for w_s = 25 nm (arbitrary units).

From Fig. 2a we observe the *E*-field is enhanced in the high-index regions, so the optical intensity there is also higher than that in the slot. The enhancement is by a factor of about 5. Light propagation in the slot waveguide shows a much higher intensity than that achievable with conventional waveguides. The vertical confinement of the *E*-field in the slot region is dictated by that in the high-index regions. From Figs. 2b and 2c we see that the field in the interstitial air is much smaller than in the high-index regions. In Fig. 2b it is smaller by a factor of about 3, and in Fig. 2c it is practically zero.

In conclusion, we have analyzed by numerical experiments the average distribution of electric field in a void structure, presenting the field in the slabs and in the interstitial air. This opens the opportunity for guiding and confining light in novel materials with low refractive index.

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