A THEORETICAL COMPARISON OF STRIP AND VERTICAL SLOT-WAVEGUIDE RESONATORS IN SILICON NITRIDE FOR SENSING PURPOSES

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For biosensing applications where small refractive index variations of the surrounding medium are monitored, light needs to have a strong interaction with such a surrounding biological medium. This is not the case for classical rib [1] and strip [2] waveguides where light is predominantly guided in the high index material. However, in slot waveguides, light is confined in a low index slot region sandwiched between two high index rails and due to the discontinuity of the electric field at the interface between the rails and slot, a significant fraction of the electromagnetic field is localized in the slot. As such slot waveguides present an interesting alternative [3] for biosensing applications especially when made using silicon nitride [4] which permits slot widths of up to 200nm and as such reachable fabrication tolerances, and reduced propagation losses [5] compared to silicon slot waveguides with its higher refractive index contrast. Furthermore, for biosensing, the wider slot facilitates sample transport [6] and using a multiple-slot structure, further enhancement of the optical confinement in low index slot regions is possible [7-8]. In this paper we present work in progress of theoretical modeling for strip, slot and multiple-slot waveguides and compare their characteristics for sensing purposes.

The electrical field of the quasi-TE mode at the wavelength of 1.3 um for the three structures is reported in fig. 1. For the strip and slot waveguides their heights are set to 300nm for good optical confinement, the strip waveguide width is of 900nm to reach single mode propagation. The width of rails for the slot waveguide is 400nm while the the slot's width is fixed at 200 nm. For the multiple-slot waveguide, its thickness is set to 400 nm to obtain a good confinement and the width of the central rail to 200 nm and that of the outer rail 250nm.The Beam Propagation Method was then used to determine the variation of effective index as a function of the add-layer refractive index changes for the three structures. For TE polarization, the effective index variation of the guided mode for the multiple-slot structure is twice that of a typical slot waveguide, and four times as much as that for strip waveguides (Figure 2) for a given variation of add-layer refractive index. The limit of detection (LOD) of the index variation is inversely proportional to these values. Thus, this clearly demonstrates the suitability of the multiple-slot structure for sensing purposes.
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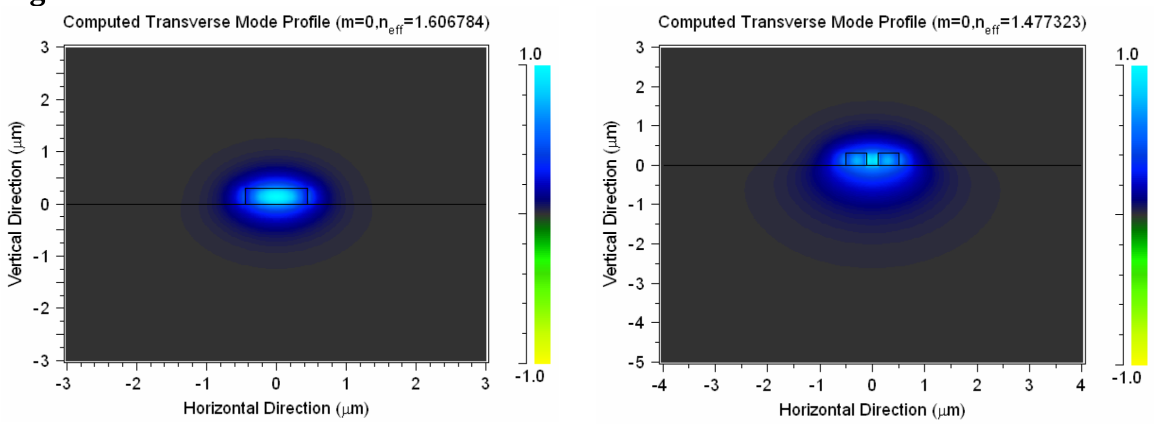
Figures:



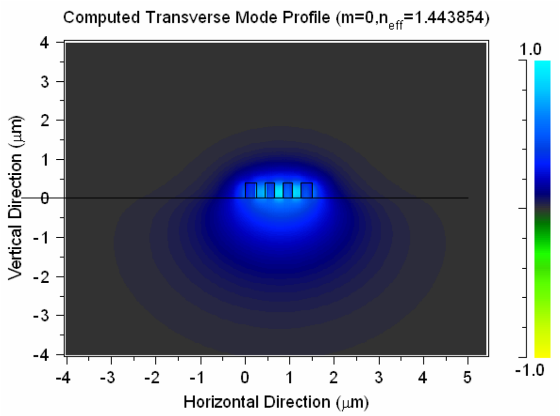


Fig 1. Optical field distribution for the quasi-TE polarization (Ex) of the three structures studied, from upper left image, clockwise: the strip waveguide, slot waveguide, multiple-slot waveguide The substrate refractive index is 1.45, that of the addlayer is that of H_2O (n=1.33) and for the waveguides is that of Si_3N_4 (n=2).

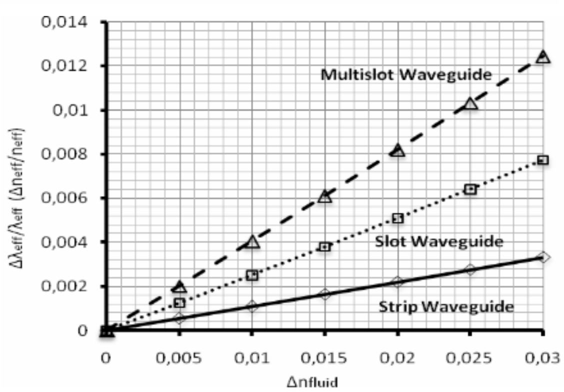


Fig 2. Simulation results for the three different waveguides. (Δn_{fluid} = change in addlayers refractive index, $\Delta n_{eff}/n_{eff}$ = change of effective refractive index normalized to the effective index for n_{fluid} = 1.33)