Dispersion engineering in Silicon Nitride waveguides

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Silicon nitride waveguide dispersion, dispersion engineering, optical frequency combs, integrated optics

SHORT SUMMARY

On the way of reaching integrated frequency comb generation, the challenge of achieving a positive dispersion parameter in silicon nitride buried in silicon dioxide platform is to be tackled. We study the conversion of the dispersion parameter of the fundamental TE-like mode from negative to positive in silicon nitride waveguide as function of the waveguide width and height. Design curves are provided to aid in the dispersion engineering process, including geometric variation of the waveguide height and the width.

INTRODUCTION

Silicon nitride waveguides buried in silicon dioxide is a well-known technology for building optical frequency combs for the optical communication and spectrometry applications [1] [2] [3]. Silicon nitride, owing to its low two photon absorption and moderate second order nonlinear coefficient, makes the highest figure of merit for integrated nonlinear optics applications [4].

To achieve frequency comb generation, optical waveguide has to have a positive dispersion parameter [5]. A well-known fact is that silicon nitride of height around 700 nm is needed to achieve positive dispersion parameter. As far as we are aware, no clear explanation for this fact has been mentioned in literature. Also, no methodical procedures for designing silicon nitride waveguides for specific applications can be found in literature.

In this work, effective index method has been used to analyze the waveguide dispersion. Using this method, the effect of various parameters including the material dispersion and the geometric dimensions are analyzed separately. Also, general design curves are presented to aid in designing silicon nitride waveguides.

This work is organized as follows; next section discusses the methodology. Then, the results are briefly discussed. Finally, the paper is concluded in the last section.

METHODOLOGY

Figure 1 shows the cross section of the waveguide, whose core dimensions are (w µm width and h µm height), and its material is Silicon Nitride (Si_3N_4), while its cladding is made of Silicon Dioxide (SiO_2).

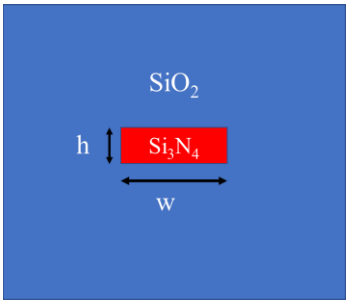

Figure 1 The layout of the cross section of the waveguide

Two techniques are used in this study; first is the semi-analytical effective index method, used to generate wide band dispersion curves. Second, to generate accurate design curves, finite difference mode solver is used. Meshing and frequency points are optimized for stable numerical results. The silicon nitride material dispersion is included in both models. The silicon nitride material model used in both cases is the Philip model [6].

RESULTS

Effective index method

Figure 2 shows the waveguide dispersion parameter of the fundamental TE-like mode at

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height 600 nm and 900 nm, along with the material dispersion parameter, and the total dispersion parameter in both cases. Both cases have a width of 3000 nm. Waveguide dispersion is obtained with refractive indices of silicon nitride and silicon dioxide set as constants, to separate the waveguide effect from the material effect.

It is clear that material dispersion parameter is always negative, and waveguide dispersion parameter is the one that pushes the total dispersion to be positive. It can also be inferred from the figures that the height of the waveguide must be increased to produce sufficient value of positive waveguide dispersion, which elevates the total dispersion parameter above zero.

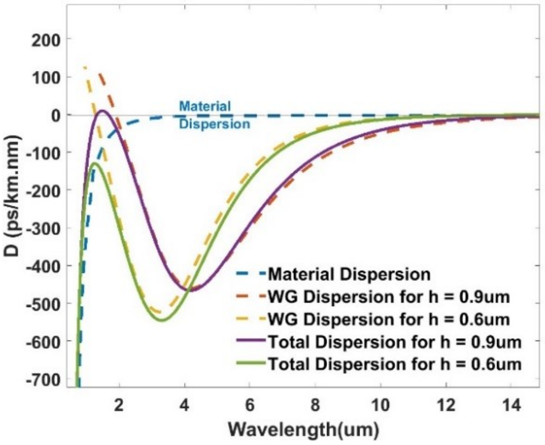

Figure 2 The waveguide dispersion parameter and the total dispersion parameter at waveguide heights (h) equal to 600 nm and 900 nm, in addition to the material dispersion parameter.

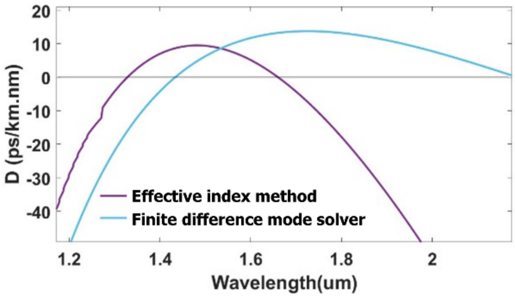

Figure 3 Waveguide total dispersion parameter at h = 900 nm, w = 3000 nm, and the finite difference mode solver results at the same dimensions for comparison.

Figure 3 compares between the effective index method and the finite difference mode solver results. The peak value of the two results are nearly the same, which means that the effective index method can predict the presence of positive dispersion at relatively the same dimensions as the finite difference method. It is also to be noted that the bandwidth of the finite difference result is wider. It is to be mentioned that more accurate forms of effective index method like the weighted index method [7] could give better results.

Waveguide Dispersion Engineering

Figure 4 shows finite difference mode solver results for the dispersion parameter at different silicon nitride widths, for 700 nm height. The curve shows how the waveguide width affects the optical band of positive dispersion parameter.

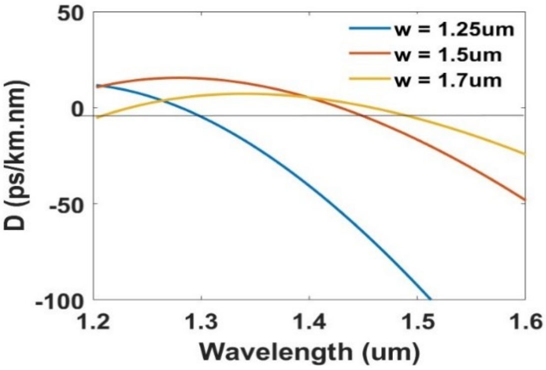

Figure 4 The effect of the width on the dispersion parameter at 700 nm height.

Conclusion

In this work, the effect of the silicon nitride height on the total dispersion parameter of the fundamental TE-like mode is discussed. It was found that a silicon nitride waveguide of height around 700 nm is required to overcome the negative dispersion of the silicon nitride. Design curves are presented to aid in the dispersion engineering process.

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