DESIGN AND REALISATION OF MONO-MODAL SiO_xN_y -BASED POLYMER WAVEGUIDES FOR ACTIVE FUNCTIONS

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Abstract

A method is described for optimising nonlinear mono-modal channel waveguides such that the guided power influences the propagation constant optimally. These waveguides have been used for a nonlinear MZI and measuring TPA. Experimental results are described.

Introduction

In nonlinear optics, one of the issues is to use the available optical power as efficiently as possible. In this abstract we will deal with a ridge type waveguide with a nonlinear cladding on a SiO_xN_y layer stack. This can be advantageous in cases where both linear (with an index matching SiO_xN_y cladding) as well as nonlinear waveguides are present in one design. In the optimal situation there are both a large part of the optical power as well as a high intensity in the nonlinear cladding layer. The problem will be described in terms of an efficiency parameter Q_2 .

Theory

For the effective index of a guided mode can be written:

$$N_{eff} = N_{eff,0} + Q_2 \cdot P \cdot n_{2I} \quad (1)$$

where P is the guided power and n_{2I} the intensity dependent refractive index (IDRI). Starting with the effective index model (EIM) and the variation theorem¹, Q_2 can be expressed as:²

$$Q_2 = \frac{\Delta N_{eff}}{P \cdot n_{2I}} = \frac{1}{N_{eff,0}^2} \iint_{NL \text{ area}} n^2(x,y) \xi_1^2(x) \xi_2^2(y) dx dy \quad (2)$$

where $\xi_1(x)$ and $\xi_2(y)$ are the normalised modal fields in cross sections perpendicular and parallel to the slab waveguide respectively.

The waveguide will be mono-modal in the lateral direction by taking a small height and width of the ridge. In the perpendicular direction, however, the situation is less obvious. Besides the fundamental mode as indicated by the dotted lines in figure 3, more guided modes seem to exist according to the EIM. For suitably chosen waveguide parameters however these modes will couple to lower order slab modes travelling at a certain angle with respect to the ridge, so that the propagation constants in the z -direction match.

Simulations

A three layer structure serves as a starting point. The substrate layer is SiO_2 ($n=1.45$) in order to have a large index contrast with respect to the guiding layer. The refractive index of the cladding is 1.65, the refractive index of the nonlinear polymer. For a fixed thickness, the core index can be changed and Q_2 can be calculated. The resulting curve as shown in figure 1 reaches an optimum for $N_{eff} = 1.66$ which pinpoints the refractive index of the guiding layer at a given thickness.

figure 1 Q_2 vs. the normalised index contrast for arbitrary ridge parameters.

At this point both the index contrast and the width of the ridge can be varied. The optimum is reached at an effective index contrast of 0.004 and a width of 2-4 μm . The results of the variations of the width at a fixed contrast of 0.004 are shown in figure 2.

figure 2 Q_2 vs. the width of a ridge at a contrast of 0.004. Also the curves of the first two modes are shown.

An improvement of the Q_2 parameter can be obtained by splitting the guiding layer in a high index (Si_3N_4 , $n=2$) and a lower index bottom layer; the field is "pushed" even further upwards. Results are summarised in table 1.

t_4 [μm]	t_3 [μm]	n_4	Q_2 [m^{-2}]
0.00	0.30	1.8499	$7.6 \cdot 10^{10}$
0.04	0.26	1.8257	$8.1 \cdot 10^{10}$
0.08	0.22	1.7877	$8.7 \cdot 10^{10}$
0.12	0.18	1.7264	$9.3 \cdot 10^{10}$

table 1 The influence of applying a Si_3N_4 top layer on the guiding layer. The parameters are defined in figure 3.

figure 3 The optimised channel structure. The intensity profiles give an impression of the localisation of the electrical field.

Results

The optimised structure as shown in figure 3 is realised. The modal profile is measured by scanning a focused laser beam ($\lambda=1.053\mu\text{m}$, waist= $2.8\mu\text{m}$) along the end face of the waveguide. The channel waveguide is clearly mono-modal as shown in figure 4. The attenuation of the waveguides is measured and is 1.5dB/cm for a SiO_xN_y cladding and 2.5dB/cm for a polymer cladding (DANS polymer of Akzo Nobel).

figure 4 The observed profile of a $2.5\mu\text{m}$ width channel waveguide.

Conclusions

With the proposed method, channel waveguides can be designed in such a way that they are mono-modal in both directions and that the optical power is utilised most efficiently in order to establish nonlinear effects. A key parameter is the so-called Q_2 . Analogue to the described technique a procedure can be developed to optimise waveguides for sensor applications. The waveguides have been used for TPA measurements², in an integrated Mach Zehnder Interferometer for demonstration of all optical switching² and with other materials for sensing applications.

References

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