Demonstration and Accurate Beam Propagation Method Modeling of Direct UV Written Shallow Angle X-couplers

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BPM modeling of UV written X-couplers shows excellent agreement with measured data by careful choice of launch conditions, index values and allowance for hydrogen out-diffusion effects. Comparison with recent analytical model is also presented.

1. Introduction

The impetus behind channel definition using direct UV writing is in its versatility and low cost. The UV writing technique allows functional components such as reflection gratings to be fabricated in a single-step process. Furthermore, it is capable of creating smooth intersections between crossing waveguide channels, overcoming blunts and step coverage problems inherent in photolithography and etching. In power coupling applications, the ability to tailor the refractive index of the coupler interaction region using UV exposure during and post fabrication is both attractive and essential. Combining direct UV writing and wet etching for example, commercial low cost gratings-based sensors can be fabricated towards industrial bio-chemical applications [1]. As the design of these devices becomes more complex, the ability to simulate their behaviour prior to fabrication is important. An accurate model must make allowances for a number of factors unique to direct UV writing such as hydrogen out diffusion, photosensitivity level saturation and proximity effects. To this end, we've developed a BPM model for shallow angle X-couplers and compared the results to both experimental and an analytical model, showing good agreement.

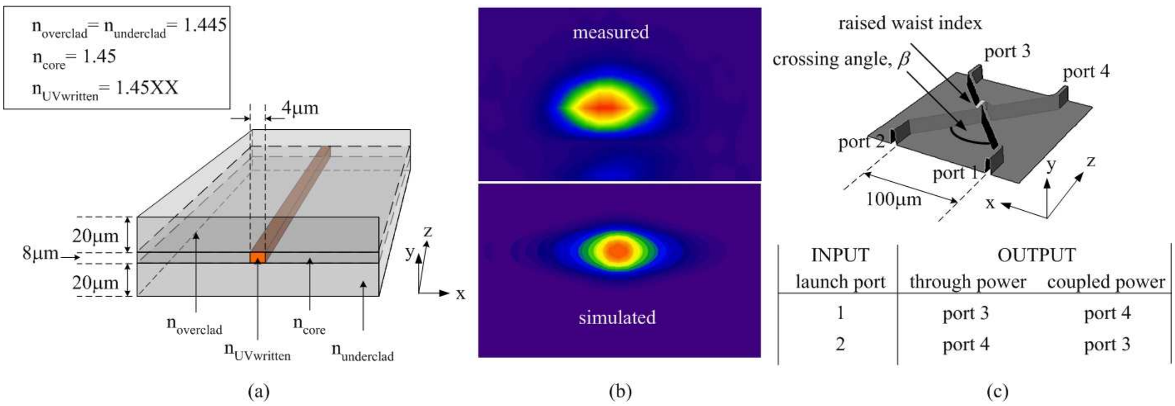
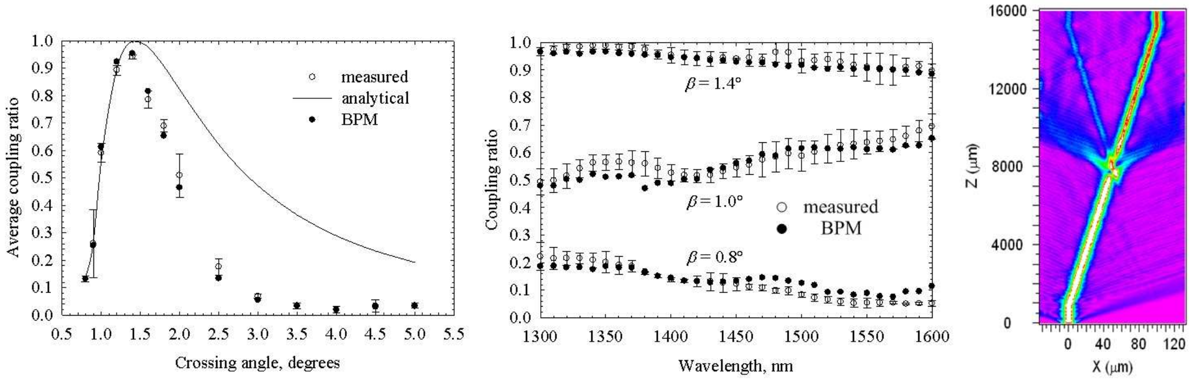


Fig.1 (a) 3-layer sample with dimensions and parameters used for simulation; (b) comparison between simulated and measured modes of straight reference channel; (c) 3D index profile of X-coupler showing raised waist index and definitions of coupled power with respect to launch port.

2. BPM Modeling and Validation

The samples used for these experiments were 3-layer non-index matched silica-on-silicon. A non-index matched sample has an oval-shaped mode profile with better confinement in the vertical direction due to the higher index contrast [3], which lowers coupling efficiency between a launch fiber and the target waveguide. To validate this observation, a straight buried channel was simulated using the parameters shown in fig. 1(a). From fig. 1(b), the measured mode profile is not perfectly oval which is believed to be caused by output facet imperfections. However, it could be seen that the modes obey the aforementioned description, being better confined vertically. Using loss values measured from a straight reference channel, the coupling efficiency between the waveguide and launch fiber is found to be about 75% and this was used in determining the launch field dimensions. In fig. 1(c), we see that the waist segment of the modeled X-coupler structure has a raised index. For the BPM model, the important parameters are the UV induced index increase of the individual channels and the waist refractive index. Typical UV induced index increase range from (1.25-1.75) x10^{-3} at λ=1550nm for the channels, with decreasing values for structures written further along the fabrication run to reflect the exponential decaying out-diffusion behavior of hydrogen in planar samples [4]. Choosing the optimized waist index value is tricky because both out-diffusion and photosensitivity locking effects need to be considered. Typical additional index of ~ 1 x10^{-3} for the waist segment with 10^{-5} index resolution is usually chosen to produce accurate coupling ratio values. Fig. 2 depicts the coupling behavior of the X-coupler showing excellent agreement between the BPM and measured data. The figure also shows the simulated field distribution of the structures.



(a) (b) (c)

Fig. 2. (a) Coupling behavior of X-couplers with crossing angle; (b) Wavelength dependency of X-couplers; (c) Simulated field distribution

Coupling ratio is the ratio of coupled to total output power (see fig. 1(c)). The solid curve in fig. 2(a) is derived from [2] where the proposed empirical equation is utilized. The disagreement with measured data is because the analytical model could only predict coupling behavior for a structure with gradual enough waveguide inclination so as to maintain adiabatic evolution (i.e. the crossing angle has to be shallow enough so as not to exceed 1°). For our BPM model, the wide angle feature of the software was employed to simulate X-couplers with crossing angles >1°. The wavelength dependency of the structures was also simulated and shows excellent agreement between simulated and measured data. Further optimization can be done by fine tuning the waist index value. Intensity dips in the broadband source used to characterize the structures led to the observed difference in measured data error levels with wavelength. The normalized simulated through and coupled powers correspond well to those measured, further validating the model. The predicted waist index from the simulated data is ~1.5Δn and this is believed to cause the scattering around the waist segment observed in fig. 2(c) and could be reduced through better mode confinement.

3. Conclusions

Successful modeling of UV written X-couplers is demonstrated with excellent agreement between measured and simulated data by considering factors unique to UV writing. This improved understanding will allow future development of custom designed X-couplers based on the UV writing platform for complex optical applications.

References

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