GaAs-Based Integration Photonics: Efficient Tapers

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***Abstract*— GaAs/AlGaAs based tapers for 1.3 µm wavelength operation and based on adiabaticity and geometry approaches are computationally designed. Both approaches estimate efficiency higher than 99% for tapers of length ~16 µm.**

Keywords*— *GaAs integrated photonics, adiabatic tapers, tapers design

I. Introduction

Tapers have promising applications such as fibre-circuit signal exchange, for interconnecting different cross-section size waveguides and/or functional elements within the circuit [1], [2], [3]. The efficiency of tapers depends on their geometry. So, the efficiency is improved by either extending tapers length or choosing a proper geometry to meet the adiabaticity. Ideally, absolute adiabaticity means a mode power does not radiate or transfer to higher order modes. Although this limit is not achievable, the geometry of tapers presented in Fig. 1 (a) can be designed for high adiabaticity. Efficient tapers can be obtained according to two approaches:

1- Adiabaticity based which guarantees high adiabatic functionality along the taper by ensuring that the local spreading of the waveguide walls, $\theta(z)$, is slower than the diffraction driven spreading of the waveguide mode ($\alpha < 1$) as stated in (1) [4].

$$\theta(z) = \alpha \frac{\lambda_0}{2W(z)n_{eff}(z)} \qquad (1)$$

where λ_0 is the input wavelength, α is an adiabaticity parameter and $n_{eff}(z)$ the effective refractive index of a mode at a local width of the waveguide $W(z)$ at position, z.

2- Geometry based where the taper shape along the propagation direction, z, is defined by the curvature constant, a [5].

$$W(z) = W_L + (W_0 - W_L)(1 - z/L)^a \qquad (2)$$

where $W_0 = W(0)$ is the initial width of the taper at $z = 0$, and $W_L = W(L)$ is the final width of the taper at $z = L$.

We have modelled taper designs to deliver light from a $W_0 = 4\mu m$ wide multimode waveguide to a $W_L = 1\mu m$ wide single mode waveguide using a fully vectorial finite difference mode solver [6] by launching a TE_{00} mode at wavelength of 1.3 µm (Fig. 1 (b)). The efficiency was simulated using an eigenmode expansion method and efficiency in excess of 99% in a length as short as 16 µm [7].

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II. Optical System

Our chosen optical system are deeply etched, high contrast GaAs/AlGaAs waveguides designed to operate at a wavelength of 1.3 µm (Fig. 1 (c)). The high refractive index of GaAs is a key feature that allows high confinement and consequently efficient components. Moreover, GaAs photonic integrated circuits have easy access to the active optical functions that silicon lacks. Our taper designs will provide one of the basic building blocks that allow greater development of GaAs photonic integrated circuits, including the access to on single chip integration for both active and passive components.

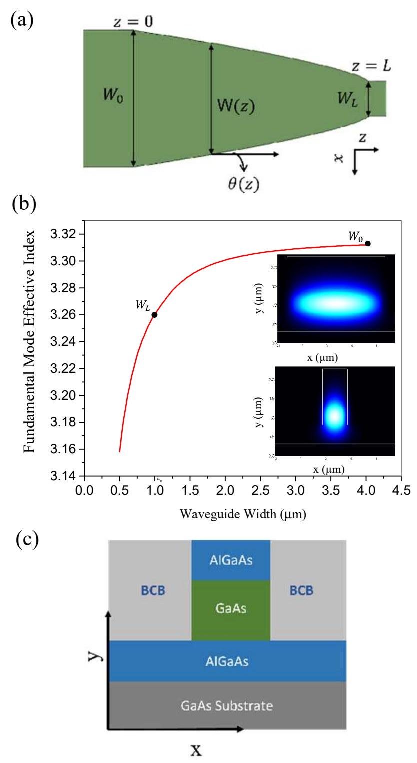

Fig. 1: (a) The schematic of the taper. (b) Fundamental mode effective index as function of waveguide width. The insets at the top and bottom show intensity profile of the fundamental mode at the beginning and end of the taper. (c) GaAs/AlGaAs passive waveguide structure.

III. ADIABATICITY BASED EFFIECINT TAPER

Fig. 2 shows the simulated power output of tapers designed with different values of the adiabaticity coefficient α, and demonstrates that for non-adiabatic tapers with $\alpha > 1.2$ there is a strong dependence of the taper efficiency on the adiabaticity coefficient. For $\alpha > 1.2$ (equivalent to taper length shorter than 16 µm and coupling efficiency of 99.2%), losses become higher and the taper is no longer adiabatic. It is interesting to note that the efficiency of the tapers starts to level off for values of the adiabaticity coefficient $\alpha = 1.2$, which is in theory non-adiabatic. This could be due to high confinement of the structure. This approach suggests only one option (taper length and shape) for each value of the adiabaticity coefficient.

IV. GEOMETRY BASED EFFIECINT TAPER

Optimizing a taper based on geometrical design rule in (2), several values (taper length, curvature constant) correspond to different tapers with different efficiencies. For lengths extending from 5 µm to 20 µm, the exponent a can be optimized to find the best taper shape. From the data in Fig. 3, the relation between the output power and (taper length, curvature constant) clarifies that longer (adiabatic) tapers have better performance while at short lengths tapers show poor functionalities for all configurations (all a values). Nonetheless, the best tapers can be optimized at relatively short lengths (~16 µm). compared to the adiabaticity based approach, this approach is of higher degree of freedom where the taper length and shape can be chosen according to the size and number of components on the chip and ease of fabrication. For example, efficiency of ~99% is expected tapers of length from 13 µm and curvature constant between 0.6 and 0.9.

V. CONCLUSION

Using two approaches, GaAs/AlGaAs based waveguide tapers have been designed. Small footprint tapers with high power transfer efficiency have been simulated.

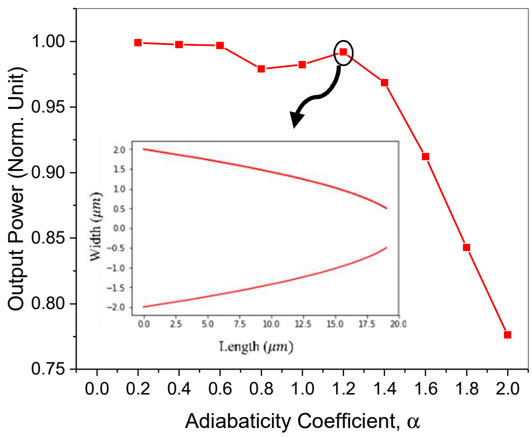

Fig. 2: Efficiency for taper designs of α=0.2 to 2. The inset is taper design for adiabaticity constant of 1.2.

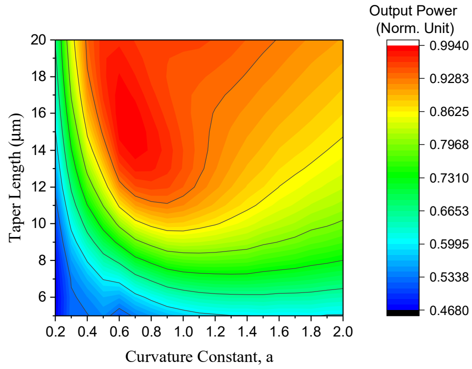

Fig. 3: Taper design based on curvature constant, a.

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