Dilute Waveguide Reflective Semiconductor Optical Amplifier for 3D Hybrid Silicon Photonics Integration

Bowen Song*[1], Youning Luo[1], Sergio Pinna[1], Yuan Liu[1] and Jonathan Klamkin[1]
Department of Electrical and Computer Engineering
University of California, Santa Barbara
Santa Barbara, USA
bowen@ucsb.edu

***Abstract*—A dilute waveguide reflective semiconductor optical amplifier for alignment tolerant hybrid silicon photonics integration was demonstrated with emitting wavelength of 1.55 μm. Far field divergence angle at fast diverge axis was 11.8° compares to conventional waveguide of 28.2°. The dilute waveguide demonstrated 45% alignment tolerance improvement with mode size of 84 μm^2.**

Keywords—Hybrid Silicon Photonics Integraion;Dilute Waveguide; Alignment tolerance;

I. INTRODUCTION

Integrated lasers have been a bottle neck for silicon photonics (SiPh). Direct epitaxy grown III-V alloys on silicon is promising but still immature [1]. Heterogeneous integration based on wafer bonding [2] also faces the challenges of limited thermal performance and low yields. 3D hybrid silicon photonics integration approach based on back-end of line flip-chip bonding was reported in [3]. Light is coupled to the silicon waveguide through surface grating coupler as shown in Fig. 1(a). Dilute optical mode has been used to increase alignment tolerance between waveguide and fiber for low cost and high throughput packaging. In this work, a dilute waveguide reflective semiconductor optical amplifier (RSOA) for alignment tolerant 3D hybrid silicon photonic integration is demonstrated. Alignment tolerance was increased by 45% at fast diverge axis using dilute RSOA. Far field divergence angle of the dilute waveguide was 11.8°, about 3 times lower than conventional design.

II. DESIGN AND FABRICATION

Figure 1 (b) and (c) shows mode simulation results for a conventional and dilute waveguide. The conventional RSOA was provided by MACOM emitting at 1.55 μm. For the dilute waveguide, guiding layer is 5 μm and the ridge width is 1.25 μm with a mode size of 84 μm^2. The mode size and overlap coefficient (γ) between optical mode and multiple quantum wells (MQWs) region varies with ridge width as it shown in Fig. 2 (a) and (b). To maintain decent γ, a straight 6μm wide ridge is used terminated by a 3 mm long adiabatic taper for mode conversion. Figure 2 (c) shows optical loss versus taper length using eigenmode expansion method. The base material is fabricated in a single-step epitaxial growth by molecular beam epitaxy. Wet etch was used for ridge define followed by waveguide passivation, P-via opening and metal deposition steps. The wafer was thinned to 150 μm with N-metal deposited on the back. Device was isolated from the wafer by cleaving and mounted on aluminum nitride carrier for testing.

III. BEAM CHARACTERIZAION

The dilute waveguide RSOA demonstrated CW lasing at room temperature with threshold current of 550 mA. The high threshold was partially due to uncoated facet. The far field beam of dilute and conventional RSOA were characterized using IR camera. By moving the camera at a step of 20μm, beam profile of the dilute and conventional waveguides was captured at around beam waist shown in Fig. 3 (a) and (b) respectively. The divergence angle measured for dilute waveguide is 11.8°, the number is 28.2° for the conventional waveguide.

IV. ALIGNMENT TOLERANCE

Alignment tolerance analysis was conducted using the 2D FDTD simulation. The coupling efficiency between the RSOA and SiPh waveguide was calculated at emitting wavelength 1.55 μm at different offset position of two chips at fast diverge axis (Δx_f). The 3dB offset length was used to quantify the alignment tolerance where the max power coupling efficiency drops half. The corresponding alignment tolerance analysis results for the 3D hybrid silicon photonics integration are shown in Fig. 4 (a). The alignment tolerance gains about 45% by using the dilute waveguide device. For comparison, identical analysis was also carried for edge coupling method with results shown in Fig. 4 (b), the tolerance gains 60% when using dilute RSOA at edge coupling.

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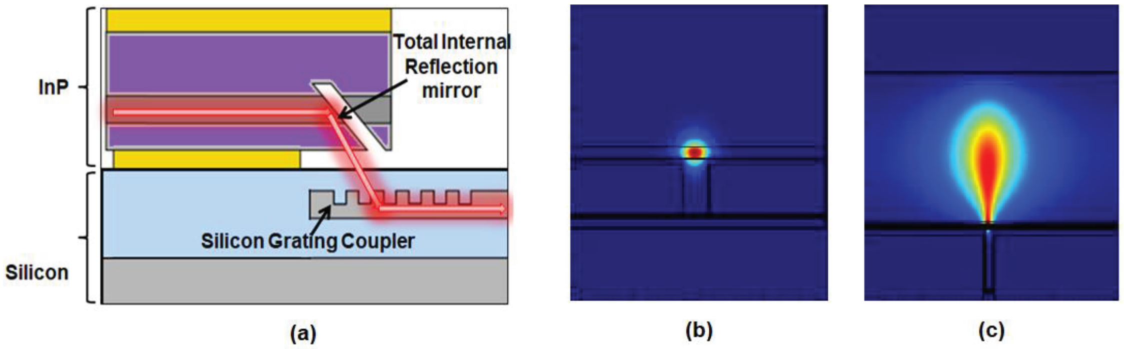

Fig.1. (a) Side-view schematics of 3D integrated hybrid silicon laser. Mode profile of (b) conventional (c) dilute waveguide.

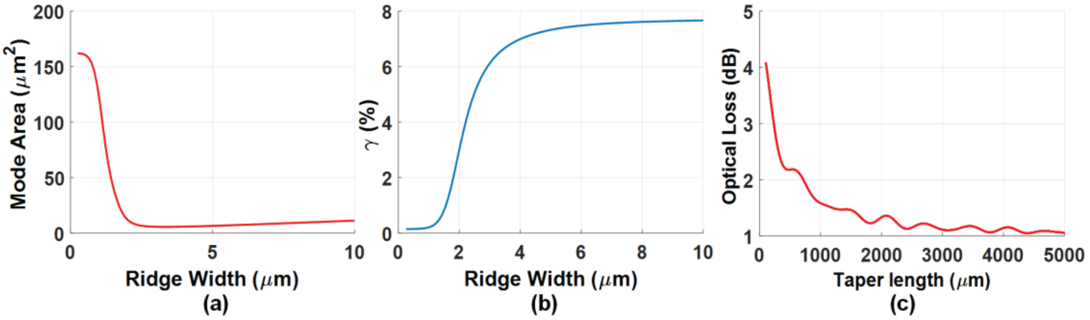

Fig.2. (a) Dilute mode size versus ridge width. (b) Dilute mode overlaps with MQWs ratio versus ridge width. (c) Taper loss versus length

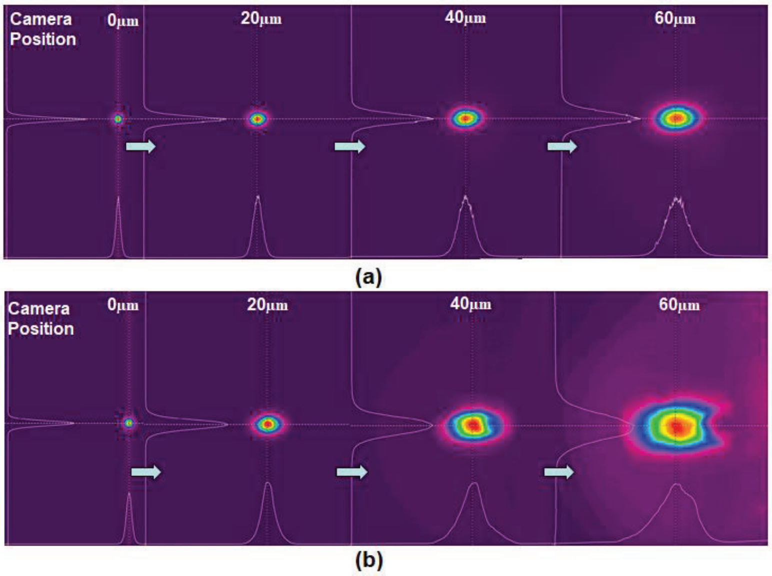

Fig. 3. Beam profile evolution of (a) dilute waveguide and (b) conventional waveguide.

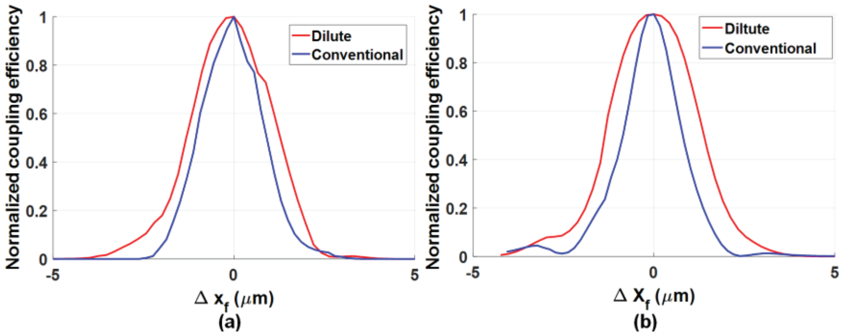

Fig. 4. Normalized coupling efficiency versus Δx_f of (a) 3D hybrid integration and (b) edge coupling.

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