InP Photonic Integrated Circuit for 2D Optical Beam Steering

Weihua Guo[1], Pietro R. A. Binetti[1], Chad Althouse[1], Ashish Bhardwaj[1], Jonathan K. Doylend[1], Huub P.M.M. Ambrosius[2], Leif A. Johansson[1], member, IEEE and Larry A. Coldren[1,3], Fellow, IEEE

[1]Department of Electrical and Computer Engineering, University of California, Santa Barbara, CA, 93106, USA.
[2]Electrical Engineering Department, Eindhoven University of Technology, Eindhoven, NL.
[3]Department of Materials, University of California, Santa Barbara, CA, 93106, USA.
Email: guow@ece.ucsb.edu

***Abstract*—InP photonic integrated circuit for 2D ($5^{\circ}\times10^{\circ}$) optical beam steering has been demonstrated for the first time. Design, fabrication, and preliminary results are presented.**

Keywords-Lidar; optical beam steering; photonic integrated circuit

I. INTROUDCTION

Electronically controlled 2D optical beam steering will become very useful for light detection and ranging (LIDAR) [1, 2]. In this work we demonstrate an InP based photonic integrated circuit (PIC) for this purpose. The critical component of the PIC is an optical phased array with embedded second-order gratings which function as out-of-plane vertical emitters, as schematically shown in Fig. 1. Wavelength tuning is employed to steer the beam in the direction along the grating (longitudinal direction θ) because the emission angle of the grating is dependent on the wavelength. Phase tuning across the phased array is used to steer the beam perpendicular to the grating (lateral direction ϕ). 2D beam steering is thus achieved by controlling both the wavelength and the phase across the phased array.

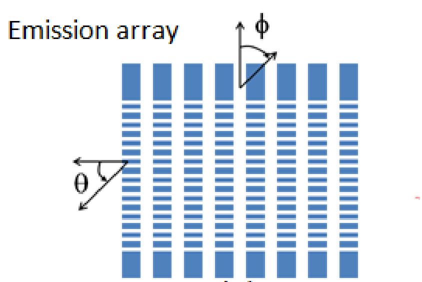


Fig. 1 Schematic structure of the emission array

II. STRUCTURE AND FABRICATION

As shown in Fig. 2, the PIC consists of an input semiconductor optical amplifier (SOA), a 1×8 beam splitter composed of cascaded 1×2 MMI beam splitters, a phase shifter (PS) array, an SOA array, the emission array composed of SOAs with embedded 2nd order gratings for out-of-plane light emission, and monitors composed of MMI splitters and photodiodes (PD) to provide feedback for the electronic control of the photonic circuit.

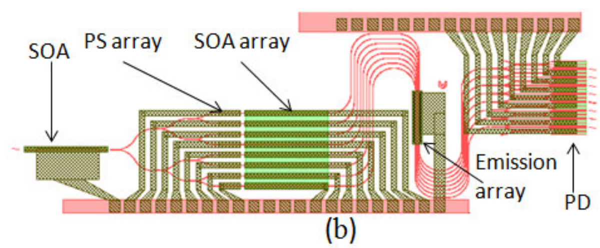
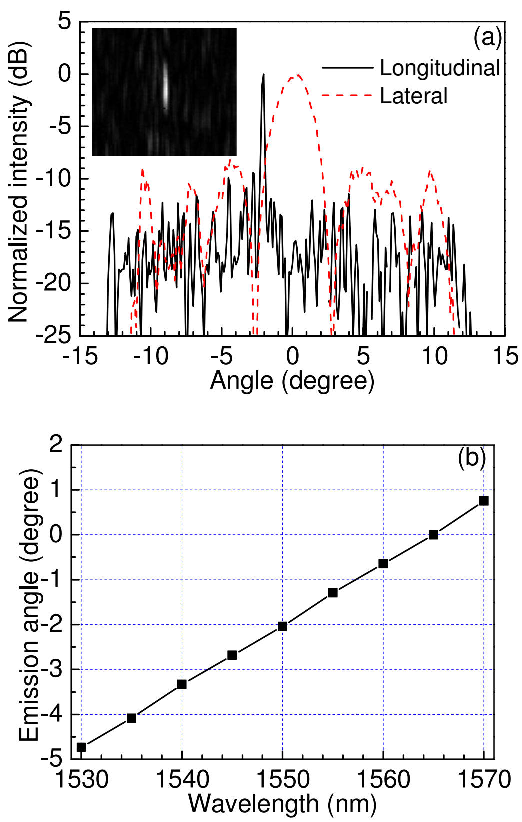


Fig. 2 Mask layout of the InP PIC

The emission array has eight channels. To make the two controls, wavelength and phase, independent of each other equal path length has to be ensured for each channel, so additional bends are added between the SOA array and the emission array. The preamplifier SOA, the phase shifters and the SOAs in the SOA array have independent contact pads as seen in Fig. 2. The SOAs in the emission array are 500µm long and 2.7µm wide and are contacted together because they are narrowly spaced (2.8µm gap). Deeply etched ridge waveguides are used to form all the waveguides in the PIC. The PIC has an overall size of about 2mm×6mm. The waveguide core consists of ten compressively strained InGaAsP quantum wells with the emission peak around 1550nm and separate optical confinement layers [3]. Quantum well intermixing technique is employed to increase the bandgap of the quantum wells to 1450nm in the regions intended for passive waveguides [4]. The 2nd order gratings are etched into the upper optical confinement layer above the quantum wells. The Bragg wavelength is designed to be 1550nm. Because of quantum well intermixing and also the grating, regrowth of the P doped upper cladding layer and the contact layer is used to finish the whole wafer structure. The emission is through the InP substrate and through a window opened in the bottom N contact metal.

III. MEASUREMENT AND RESULTS

The output from an external tunable laser is fibre coupled into the input waveguide of the PIC and preamplified by the input SOA biased at 200mA, then split into eight equal channels. They then pass through the phase shifters and the SOAs and enter into the emission array and emit perpendicular to the PIC. Although the SOAs in the SOA array have independent contacts, they are connected together and have current injected through a single source meter for the ease of these preliminary measurements. A total current of 800mA was injected into the SOA array. The emission array has a total current injection of 500mA. The phase shifters are individually controlled by source meters. The far field of the emission is monitored by an infrared imaging system which has the ability to resolve an angle range of $(\pm 17.5^{\circ}) \times (\pm 13.9^{\circ})$ with the resolution of ~0.1°. The current injection into each phase shifter was varied to maximize the side lobe suppression in the angle range from -10° to 10° through the Particle Swarm Optimization (PSO) algorithm [5]. The inset of Fig. 3 (a) shows the far field pattern for 1550nm captured by the infrared camera after the PSO optimization. The field distribution along the longitudinal and lateral direction across the peak is shown in Fig. 3(a). As expected, the beam is very narrow in the longitudinal direction because of the long emission length of the active grating while is broad in the lateral direction because the whole emission array is just about 40µm wide. The backside surface of the PIC is not polished, which causes scattering as seen from the inset. The peak position in the longitudinal direction versus wavelength is shown in Fig. 3(b). A slope of 5°/40nm is in good agreement with the design. The emission angle for 1550nm is -2° which means that the effective index is overestimated by about 1.3% in the design. This level of overestimation is reasonable for active waveguides with current injections, where the injected carriers reduce the effective index.



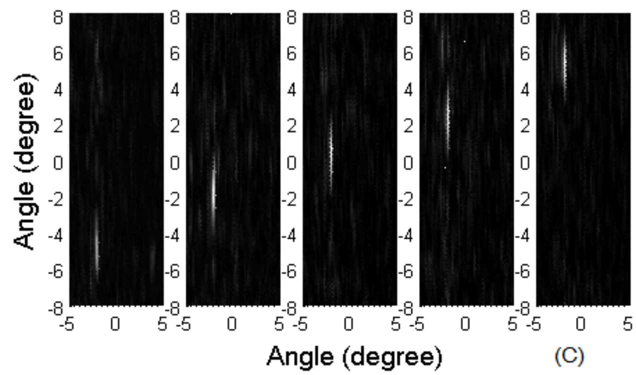


Fig. 3(a) Far field distribution in the longitudinal and lateral direction. The inset shows the picture captured by the camera. (b) Peak position in the longitudinal direction versus wavelength. (c) Beam steering with phase shifter current variations.

For each wavelength in the range from 1530 to 1570nm, the phase shifter currents can be varied to make the beam steer to any angle in the range from -5° to 5° in the lateral direction. Fig. 3(c) shows the result for the 1550nm wavelength steered to the angle of -5°, -2°, 0°, 2° and 5°.

IV. SUMMARY

Electronically controlled 2D optical beam steering has been demonstrated for the first time on a monolithically integrated active/passive InP PIC. Preliminary measurements demonstrated 5° longitudinal beam steering and 10° lateral beam steering by wavelength and phase tuning, respectively.

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