Large-scale InP Photonic Integrated Circuit Packaged with Ball Grid Array for 2D Optical Beam Steering

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Abstract: Large-scale InP photonic integrated circuit containing 1×32 optical phased array packaged with ball grid array has demonstrated two-dimensional (2D) optical beam steering.

OCIS codes: (250.5300) Photonic integrated circuits; (280.3640) Lidar;

1. Introduction

Electronically controlled two-dimensional (2D) optical beam steering is potentially useful for light detection and ranging (LIDAR), secure laser communication, printing, etc. Recently we have demonstrated an InP photonic integrated circuit (PIC) consisting of an optical phased array (OPA) with embedded surface-emitting gratings for this purpose [1]. The OPA consisting of 8 waveguides was controlled to steer the beam in the lateral dimension perpendicular to the waveguide in the array while wavelength tuning was used to steer the beam in the longitudinal dimension along the waveguide in the array [1]. In this work the waveguide number in the OPA has been upgraded to 32 so that the PIC is larger and contains many more diodes. To make contacts to all the diodes and control them, a packaging scheme based on ball grid array has been developed. Finally the packaged PIC has successfully demonstrated 2D optical beam steering.

2. Layout of the PIC and packaging strategy

Fig. 1 (a) shows the layout of the PIC. The left side contains two ports: one is for the output of the on-chip sample-grating DBR (SGDBR) widely tunable laser; the other one is for the external input. The beam splitter is a simple star coupler which has two inputs and 32 outputs: the input beam from either the on-chip SGDBR laser or the external input is split into 32 channels. Each channel has its own phase shifter followed by a high power semiconductor optical amplifier (SOA). After amplification the light enters into the grating region for out-of-plane emission. The emission is downward through the substrate. On top of the grating there is gold reflector which makes the emission uni-directional. After grating is the on-chip monitor array [1]. The PIC contains 104 diodes in total. To test the PIC a way of packaging is needed: the PIC is first flip-chip bonded onto an optical carrier; then the optical carrier is soldered onto a print circuit board (PCB) called intermediate board; finally the intermediate board plugs into a big PCB board which connects to DAC cards and high power current sources. In order to solder the optical carrier onto the intermediate board, first solder spheres with 300 μm diameter were fixed onto pads of the intermediate board using a stencil; then the optical carrier with matching pads was placed onto these solder spheres with the alignment carried out by a flip-chip bonding machine; finally the solder spheres were melted. Fig. 1(b) shows an image of the optical carrier soldered onto the intermediate board. This is similar to the ball grid array packaging technique used broadly in electronics, with the modification that the solder spheres were placed on the PCB board. A micro-channel cooler was soldered onto the backside of the carrier to cool the optical chip when high current was pumped into the SOA array. The final packaged system is shown in Fig. 1 (c).

3. Measurement

Two DAC cards were used to control the 32 phase shifters. The input signal to the PIC was fiber coupled from an external tunable laser. The 32-SOA array was biased together by a high power current source with each SOA having the current about 300 mA. The emission from the gratings was monitored by a far-field imaging system consisting of three lenses and an infrared camera [1]. First the input wavelength was fixed at 1550 nm and the current injected into each phase shifter of the 32-phase shifter array was adjusted to steer the beam to a specific angle in the lateral direction. The side-lobe suppression within the angle range from -10° to 10° around the selected angle was optimized through the particle swarm optimization algorithm [1]. A typical result of the beam pointed at the lateral 0° angle is shown in Fig. 2, where Fig. 2(a) shows the 3D plot and (b) shows the beam profile across the peak in the longitudinal and lateral directions. The full width half maximum (FWHM) of the beam is 0.3 degree in the longitudinal direction and 1.2 degrees in the lateral direction. The side lobe suppression is about 15 dB. Then the phase shifter currents were adjusted to steer the beam laterally to -5°, 0°, and 5°, respectively. The beam profiles in the lateral direction are shown in Fig. 3 (a). Because non-uniformly spaced array is used, higher order diffraction peaks disappear. This is very different from the case when uniformly spaced array being used [1]. Then the input wavelength was changed from 1540 to 1570 nm, and the phase shifter currents were adjusted accordingly to keep the beam pointing at the lateral 0° angle. Fig. 3 (b) shows the beam profiles in the longitudinal direction for the wavelength of 1540, 1550, 1560, and 1570 nm, respectively. The intensity changes due to the dependence of gain on wavelength.

4. Summary

In summary large scale InP PIC with 1×32 OPA and 104 diodes has been packaged and has demonstrated 2D optical beam steering by a combination of wavelength tuning and OPA control.

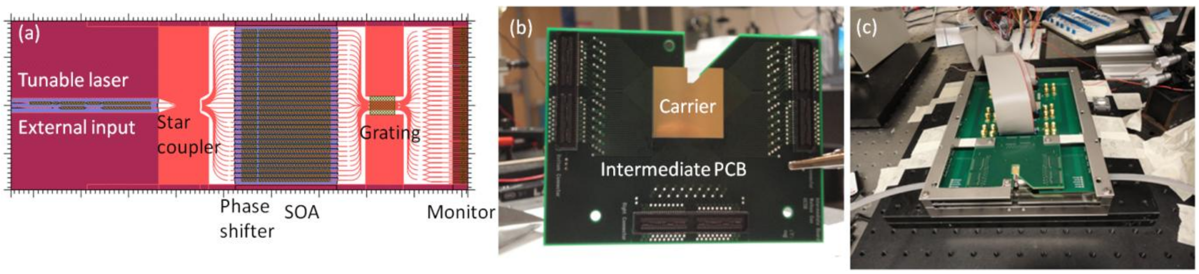

Fig. 1 (a) Layout of the PIC; (b) Carrier with PIC soldered onto the intermediate PCB board; (c) Packaged system

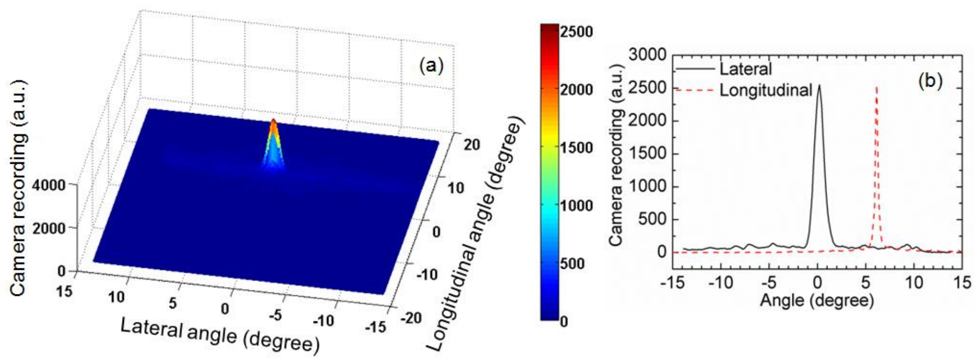

Fig. 2 (a) 3-dimensional plot of the beam spot; (b) Beam profile across the peak in the longitudinal and lateral directions.

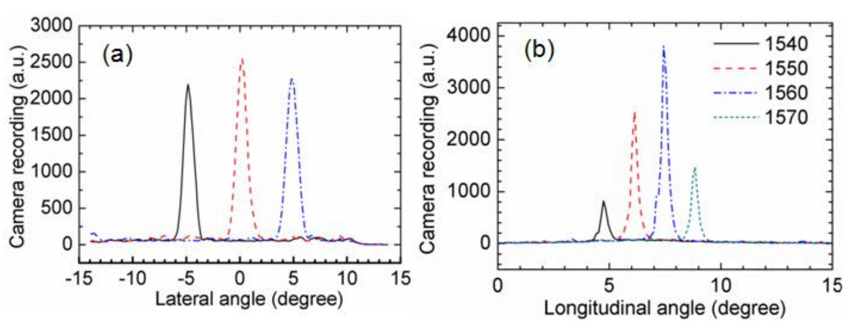

Fig. 3 (a) Beam profiles for different lateral angles and the same wavelength of 1550 nm; (b) Beam profiles for different wavelengths and for the same lateral angle of 0°.

5. Reference

[1] W. H. Guo, P. R. A. Binetti, C. Althouse, M. L. Masanovic, H. P. M. M. Ambrosius, L. A. Johansson, and L. A. Coldren, "Two-dimensional optical beam steering with InP-based photonic integrated circuits," Special issue on semiconductor lasers, J. Sel. Topics Quantum Electron., 2013.