Very Fast (>10^7 degree/s) 2D Optical Beam Steering through an InP Photonic Integrated Circuit

Weihua Guo[1], Pietro R. A. Binetti[1], Chad Althouse[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*—**Very fast (>10^7 degree/s) 2D optical beam steering through an InP photonic integrated circuit has been demonstrated.

Keywords-Lidar; optical beam steering; photonic integrated circuit

I. INTROUDCTION

Electronically controlled optical beam steering has many potential applications such as light detection and ranging (LIDAR), 3D imaging, precision targeting, etc. Several methods have been demonstrated before to achieve this goal [1-2]. One of the advantages of electronically controlled beam steering is that the beam can potentially be swept between different directions very fast. In [3] we demonstrated electronically controlled 2D optical beam steering through an InP photonic integrated circuit (PIC). In this work we show that the InP based PIC can sweep the beam in 2D very fast, with the actual sweeping speed higher than 10^7 degree/s.

II. LAYOUT OF THE PIC

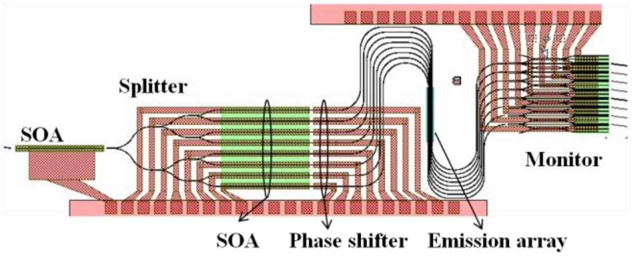

Fig. 1 Layout of the InP PIC

Fig. 1 shows the layout of the PIC. It consists of an input semiconductor optical amplifier (SOA); a 1×8 splitter consisting of cascaded 1×2 MMIs; SOAs followed by phase shifters in each channel; the emission array consisting of a passive waveguide array of which each waveguide has buried 2nd-order gratings for the out-of-plane emission; an array of interferometer monitors monitoring the phase difference between adjacent channels. The gratings are etched in the upper confinement layer of the waveguide core and buried by the re-grown P-doped cladding layers. The emission from the grating goes equally upward and downward. The far-field of the downward emission is captured by an imaging system backed up by an infrared camera. The 2D beam steering mechanism is as explained in [3]: when changing the input wavelength the beam is swept along the grating (horizontally in the image taken by the camera – see Fig. 2); when adding a phase slope across the array through those phase shifters, the beam is swept perpendicular to the grating (vertically in the image).

III. EXPERIMENT

The input signal to the PIC is fiber coupled from another InP PIC hosting a sampled-grating DBR (SGDBR) laser. As described in [4], the SGDBR laser source consists of a back mirror section, phase section, gain section, front mirror section, and a front SOA section. The currents injected into all these sections are fixed except the front mirror section which is controlled by a function generator (FG). The DC offset of the FG is used to select the super modes of the SGDBR laser which are 6 nm apart. First the DC voltage is set at 0.99 V to peak up a super mode at 1540 nm. All the SOAs in the PIC are injected with 100 mA current. All eight channel SOAs have current injected through a single current source. To account for the unavoidable series resistance difference, variable resistors are connected in series to these SOAs and adjusted to make the current injected into each SOA the same. Seven of the eight phase shifters connected with 50 Ω resistors in series, are controlled by seven FGs. First the DC offsets of the FGs are adjusted to optimize the phase profile across the emission array in order to make a good beam pointing at the vertical 0° angle. The far-field image taken by the camera is shown in Fig. 2 (a). A spot corresponding to the 0th order diffraction beam can be clearly seen. Then the DC offset is adjusted to make the 0th order beam pointing at -10°. Now the +1st order diffraction beam which is 16° apart from the 0th order diffraction determined by the 5.5 μm array pitch, is also captured by the camera as seen from Fig. 2 (b). The imaging system can capture ±14° vertically. Then the FGs are set to output square waves at 1 MHz repetition frequency with the DC offsets being the average of the above two DC sets and the peak-to-peak amplitude being the differences. These FGs are synchronized by using one of them as the master FG whose synchronization output is split and used to trigger the other slave FGs. The square wave sweeps the beam between the two angles—0° and -10° at 1 MHz speed, which is much faster than the 60 Hz frame rate of the camera. The image taken by the camera shows the spots corresponding to the two angles simultaneously as seen from Fig. 2 (c). We also put a detector 15 cm above the grating array. The detector is positioned to maximize its output signal when the 0th order beam is pointed at 0°. When the beam is quickly sweeping between the two angles 0° and -10°, the signal from the detector is recorded by an oscilloscope and shown in Fig. 2 (d). A square wave is clearly seen even as the signal captured is very weak. The square wave result means that the sweeping speed has reached $10^{\circ}/0.5\ \mu s = 2\times10^{7}$degree/s.

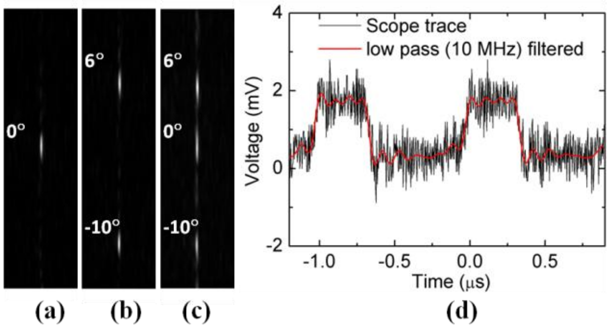

Fig. 2 (a)-(c) Images taken by the infrared camera when the 0th order beam is pointed at 0° and -10° and swept between them; (d) Scope trace when fast sweeping between 0° and -10°.

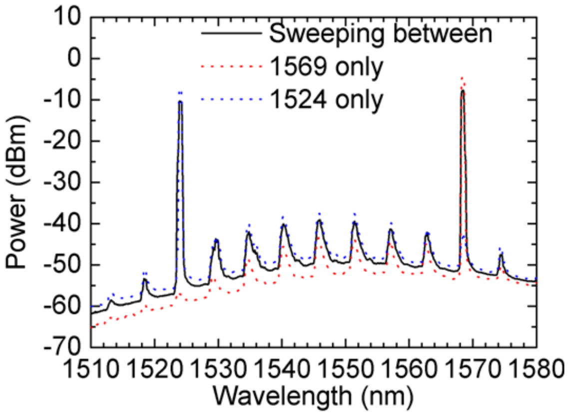

Fig. 3 Output spectrum of the SGDBR laser.

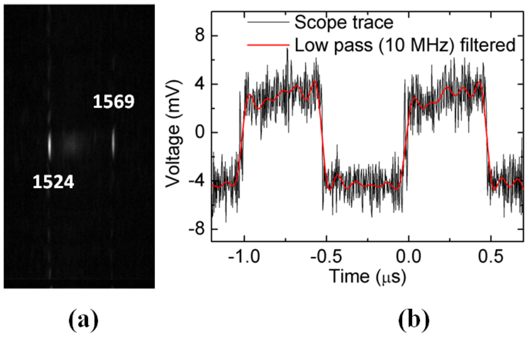

Fig. 4 (a) Image taken by the infrared camera and (b) scope trace when the SGDBR laser is fast switching between 1569 and 1524 nm.

To demonstrate the fast beam steering in the perpendicular direction, we sweep the beam along the grating by quickly changing the output wavelength of the SG-DBR laser. The phase shifter biases are recovered to DC and optimized to make the 0th order beam pointing at 0° vertically. First the DC offset of the FG that controls the front mirror of the SGDBR laser, is set at 1.62 and 1.81 V, respectively. The output wavelength of the SG-DBR laser is 1569 and 1524 nm, respectively as seen from Fig. 3. Then the FG is set to output a square wave at 1 MHz with the DC offset being 1.71 V and peak-to-peak amplitude being 0.19 V. This square wave makes the output of the SG-DBR laser switch very fast between these two wavelengths. Because the scanning speed of the optical spectrum analyzer is rather slow it captures the two wavelengths simultaneously as seen from Fig. 3. For the same reason the camera captures the two spots simultaneously corresponding to the two beams pointing at two angles 6° apart horizontally, as seen from Fig. 4 (a). To make sure the wavelength is really switching at 1 MHz speed, we tap 5% of the output of the SG-DBR laser and pass it through a 0.35 nm filter. The filter is tuned to 1569 nm to allow only one wavelength pass through. The transmission is recorded by a fast photodiode with TIAs. The response from the PD is recorded by the oscilloscope and the scope trace is shown in Fig. 4 (b). It is seen that a switching speed of 1 MHz is achieved, which corresponds to a sweeping speed of 1.2×10^{7} degree/s.

IV. SUMMARY

So in summary, very fast sweeping ($>10^{7}$ degree/s) has been demonstrated for 2D beam steering through an InP photonic integrated circuit.

Acknowledgement

This work is supported by DARPA SWEEPER project.

Reference:

[1] P. F. McManamon, T. A. Dorschner, D. L. Corkum, L. J. Friedman, D, S. Hobbs, M. Holz, S. Liberman, H. Q. Nguyen, D. P. Resler, R. C. Sharp, and E. A. Watson, “Optical phased array technology,” Proc. IEEE vol. 84, 1996, pp. 268-298.

[2] K. Van Acoleyen, W. Bogaerts, J. Jagerska, N. Le Thomas, R. Houdre, and R. Baets, “Off-chip beam steering with a one-dimensional optical phased array on silicon-on-insulator.” Opt. Lett., vol. 34, 2009, pp. 1477-1479.

[3] W. H. Guo, P. R. A. Binetti, C. Althouse, A. Bhardwaj, J. K. Doylend, H. P. M. M. Ambrosius, L. A. Johansson, and L. A. Coldren, “InP photonic integrated circuit for 2D optical beam steering,” Post-deadline paper, IEEE Photonics 2011 (IPC11), Arlington, Virginia, USA, 2011.

[4] L. A. Coldren, “Monolithic tunable diode lasers,” IEEE J. Sel. Topics Quantum Electron., vol. 6, 2000, pp. 988-999.